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Discount Factors and Risk Aversion in Managing Random Fish Populations

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Introduction

The standard literature (see Clark 1976, 1980; Anderson 1977; and references therein) on dynamic, deterministic fishery optimization models has stressed the importance of the discount factor (1/1+i, where i is the interest rate) in determining optimal harvesting strategies. The discount factor has been emphasized because an optimal harvesting strategy depends continuously on the discount factor, and a stock will be optimally depleted if the rate of growth of the population is less than the rate of discount (Reed 1974; Clark 1976). Related results have been established for stochastic harvesting models (Reed 1974; Mendelssohn 1980b; Mendelssohn and Sobel 1980), though in stochastic models a stock may become depleted even if it isn't harvested to depletion.

The presumed sensitivity of an optimal harvesting strategy to changes in the discount factor is important since a standard procedure for representing increased risk to a manager of a fishery in face of uncertainty is to decrease the discount factor. Even at first glance this is a naive approach, since it assumes a constant attitude towards risk regardless of the initial population size or harvest decision.

What would appear to be a more sophisticated approach towards risk is to assess the manager's utility function and use this as the objective function. This approach to managing fisheries and other natural resources is given in Hilborn and Walters (1977), Keeney (1977), and Holling (1978); a general discussion can be found in Keeney and Raiffa (1976).

In this paper, several of these strands are examined for one empirical stochastic model of a fishery. In particular, the actual sensitivity of an optimal harvesting strategy to changes in the discount factor are compared to its sensitivity to changes in the degree of risk aversion in the utility function. Further changes in the population dynamics when following an optimal

harvesting policy are examined as both the discount factor and the degree of risk aversion vary. The results suggest that (1) policy often is insensitive to changes in the discount factor over a range of values most likely to be found in practice; and (2) that, while a discount factor adequately represents intertemporal preferences for a certain dollar now versus a certain (expected) dollar in the future, it does not adequately capture the intertemporal preference for the gamble involved in obtaining an expected dollar in the future. Moreover, as will be shown, since risk-averse utility functions can be viewed as total revenue curves with marginal price sensitive to supply, the results suggest that highly supply-sensitive prices will exert a stabilizing effect on the optimal harvest of fish, when the fishery is assumed to be either economically or biologically stochastic. Since most if not all fisheries are stochastic, the usual assumption of perfect competition in fishery economic models and the lack of attention to risk preferences limit the usefulness of the results derived from these other models.

External decisions for a fishery, such as entry decisions and enhancement projects, depend on the valuation of the fishery, that is the discount factor used, the utility function chosen, and the sample-paths of the random harvest stream. The fishery manager usually can control only the last aspect. The results of this paper suggest that under optimal management, external decisions will not be strongly affected by this choice of policy.

Finally, as the degree of risk-aversion increases, the amount harvested is not strictly non-decreasing for all population sizes. This is seemingly in contradiction with the results of Cropper (1976); however, an intuitively appealing explanation for this result is given.

The Model

The model to be analyzed is a stochastic version of a Ricker spawner-recruit curve put forward by Mathews (1967) for salmon runs in Bristol Bay. Let x_t be the recruits in period t, and y_t the spawners. If x is observed and a decision y is taken, a one-period utility g(x, y) is received. Without loss of generality, g(x, y) can be the expected value (over the random variable θ) of some other utility h(x, y, θ). Hence the model indirectly includes economic uncertainty.

The utility in period t is discounted by a factor β, $0 \leq \beta < 1$. The recruits in period t+1 are a random function of the spawners in period t and a random variable d,

$$(1) \quad x_{t+1} = d\ 4.084\ y_t \exp\{-0.8\ y_t\};\ \ln d \sim N(0,\ \ )$$

The problem is to maximize the expected discounted utility:

$$(2) \quad \text{maximize} \sum_{t=1}^{\infty} \beta^{t-1} g(x_t, y_t)$$

$$\text{s.t.} \quad x_t \geq y_t \geq 0;\ (1).$$

Computational techniques for solving (2) and related policy questions are discussed in Mendelssohn (1980b). A 100-point grid is used with no absorbing (zero) population size.

Two different utility functions are examined for g(x, y). The first is $v_1 = 0.5 \ln(x_t - y_t)$ while the second is $v_2 = (x_t - y_t)^{\lambda}$, for λ = 0.05, 0.1, 0.25, 0.5, 0.75, 0.9, 0.95, 1.0. These utility functions are plotted in Fig. 1.

Utility functions are said to be absolute risk averse (Merton 1969, 1971; Keeney and Raiffa 1976) if $-u''(z)/u'(z) > 0$ for a function $u(z)$. The Pratt measure of relative risk aversion is $-u''(z)z/u'(z)$. Basically, a utility function is risk averse if a certain return is preferred to a lottery with equal or greater value in expectation.

The two utility functions v_1 and v_2 are members of the HARA (hyperbolic absolute risk averse) family of utility functions (Merton 1969, 1971). In particular, if R_1 is the measure of absolute risk aversion, and R_2 is the measure of relative risk aversion, then for v_1, $R_1 = 0.5/z$ and $R_2 = 1$; for v_2, $R_1 = (1-)/z$ and $R_2 = 1- $, where $z = x-y$ is the amount harvested. Both v_1 and v_2 have constant relative risk with respect to the amount harvested. However, it is clear that the relative risk aversion for v_2 changes linearly with λ. Hence λ is a measure of the relative degree of risk aversion. For λ approaching zero, the manager is totally risk averse, while for $\lambda = 1$ the manager is risk neutral. The utility function v_1 can be seen to be the limiting case of v_2 as λ approaches zero.

The utility functions v_1 and v_2 are not as rich as they might be given that they only depend on (x_t, y_t) through $z_t = x_t - y_t$. However, there exists little empirical basis for choosing more complicated utility functions that can be given meaningful, practical interpretations. Both v_1 and v_2 can be viewed as total revenue curves. Taking derivatives $v_1' = 0.5/z$ ($v_2' = \lambda z^{\lambda-1}$) and $v_1'' = -0.5/z^2$ (resp. $\lambda(1-\lambda)z^{\lambda-2}$). The first derivative is the marginal price for a supply of z units of fish, with the marginal price decreasing with increasing supply. Therefore, using v_1 and v_2 as the one-period utility functions can be viewed as examining the effect of dropping the usual economic assumption of perfect competition. This is treated analytically in some in detail in Mendelssohn and Sobel (1980).

Results

Optimal harvesting policies and optimal population dynamics were calculated for both classes of utility functions for discount factors of 0.99, 0.95, 0.925, 0.9, 0.85, 0.80, and 0.70. These discount factors are equivalent to interest rates of 1, 5.23, 8.1, 11.1, 17.65, 25, and 42.86%. Results are shown only for the utility function $v_1 = 0.5 \ln (x-y)$ and several of the extreme values of the discount factor. The results using v_2 with any value of λ are nearly identical as to those presented for v_1, and the graphs change uniformly
2 with β, so the graphs shown represent the extreme changes. Figs. 2(a)-(d) present the results.

Fig. 2(a) shows an optimal harvesting strategy, and Fig. 2(b) shows the optimal number of spawners for $\beta = 0.99$, 0.925, and 0.70. Besides the fact that visually the curves are extremely similar, between $\beta = 0.99$ and $\beta = 0.70$ the graphs are identical at 50 out of 100 states and differ by only one-grid point at the rest of the states. Moreover, it can be shown that this result remains valid for much finer grids, hence the two policies can be made to be extremely close together.

Fig. 2(c) shows the long-run (ergodic) population sizes as a rough measure of the effect each of the optimal policies has on the population dynamics. There is a slight shift to smaller population sizes as β decreases. However, the cumulative ergodic harvest distribution for the three optimal policies are virtually indistinguishable.

Fig. 2(d) shows an optimal value function, $\sum_{t=1}^{t} \beta^{t-1} v_1(t)$ when starting in each state, for $\beta = 0.99$ and $\beta = 0.925$. Despite the fact that almost identical sample paths are generated by the two optimal harvesting strategies, the change in the valuation of the sample paths is dramatic.

There has been much discussion in the fisheries literature on the appropriate value of the discount factor (Walters 1975; Clark 1976; Walters and Hilborn 1976; Holling 1978). This discussion can be divided into two components--the discount factor that should be used by an external agency such as a government agency (say to compare the benefits derived from a stream enhancement project) or a private individual (when making an entry decision, for example) to evaluate the fishery, and that used by the fishery manager to set policy, bearing in mind the effects harvest policy will have on the former decisions. If the previous empirical results are robust, they suggest that the fishery manager need not worry greatly about the exact choice of the discount factor used for determining policy, and that this choice will have little bearing on entry decisions or enhancement projects. This is because a nearly optimal expected present value will be found over a broad range of discount factors that might be used by the external agents.

3 Figs. 3(a)-(e) show similar results for v_2 with $\beta = 0.95$ and $\lambda = 1.00$ and $\lambda = 0.05$. Runs were performed for $\lambda = 1, 0.95, 0.9, 0.8, 0.5, 0.25$, and 0.05 and for different values of β. The results were not sensitive to the particular value of β used. The results changes uniformly with λ, hence the curves for $\lambda = 1.00$ and $\lambda = 0.05$ represent the extreme curves found.

Fig. 3(a) shows an optimal harvesting policy for each of the two values of λ. For $\lambda = 0.05$, more is harvested at lower population sizes, while less is harvested at larger population sizes. The crossover point is at a population size of 1.89×10^6, which is where the equation $\bar{d}$ $4.082\ y \exp\{-0.8\ y\}$ has a value equal to $y = 1.89 \times 10^6$. Thus in expectation, an individual just replaces itself. Fig. 3(b) shows an optimal number of spawners. Fig. 3(c) shows the ergodic population densities when following the two optimal policies, and Fig. 3(d) shows the cumulative ergodic harvest distributions when following

the two optimal policies. The cumulative harvest distributions differ by as much as 8%, and at the most likely harvest sizes, differ by about 5-6%. These differences are small but significant--the lower values of λ can be seen to produce a "smoother" harvest in the long run.

These results can best be explained by considering the economic interpretation of the utility functions. At $\lambda = 1$, the price does not vary with supply (in fact it is $p = 1$, which can be viewed as the normalized price), therefore a harvest policy is based entirely on being as close as possible to the point of largest overall expected growth. However, at $\lambda = 0.05$, at low populations, the higher price (resp. the higher risk) makes it desirable to harvest some now (resp. the risk makes it desirable to obtain some amount of certain return now). At higher population levels, a balance must be maintained between a desirable price and future growth. For $y \geq 1.89$, the expected value of x_{t+1} is less than y_t. Harvesting more now lowers the present marginal price per unit of fish, but increases the probability (resp. decreases the risk) of larger population sizes next period (resp. of small, unprofitable harvests next period).

The problem of unsmooth harvests from random populations is discussed in Mendelssohn (1976, 1980a, 1980b), Beddington and May (1977), and May et al. (1978). These empirical results suggest that unsmooth harvests have been found in the past because no effort has been made to include either attitudes towards risk, or marginal prices that are sensitive to supply. A reasonable conjecture is that all other things being equal, for a properly managed random fishery, wider fluctuations in catch will be expected either if outside supplies affect prices or if the entire quota cannot be taken by the fleet. Conversely, smaller fluctuations will be expected when the marginal price is very sensitive to the supply of the managed stock of fish only. Inventories

can be viewed as an outside supply that affects price, and they should have a very destabilizing effect if not taken into account in setting management policy for biologically random fisheries. This is precisely what has been seen in the salmon fishery in Alaska.

The solution of problem (2) offers some insights into relative risk aversion and planning horizons when optimal policies are followed. This is because (2) can be solved by solving the following sequence of recursive equations:

$$f_n(x) = \max_{0<y<x} \{g(x, y) + \beta E f_{n-1}(s[y, d])\}$$

where n denotes the number of periods remaining in the planning horizon. For problem (2), each $f_n(\cdot)$ is concave and continuous (Mendelssohn and Sobel 1980), and hence each is a risk averse utility. Each $f_n(x)$ is the utility of having x units of fish when there are n periods left when following an optimal policy. Hence $f_n'(x)$ is the marginal value of one additional unit of fish with n periods remaining, and the two risk averse measures R_1 and R_2 can be calculated as n changes (derivatives are approximated by finite differences). The measure R_2 reflects the relative risk aversion faced by the decisionmaker given the actual sample paths that will occur when following an optimal policy.

e 1 Table 1 gives the values of R_2 for several values of λ and for n = 2, 3, ..., 10. What is noticeable is that the relative risk for f_n is much less than that for v_2, that it increases with n, and that it quickly becomes stationary after 3-5 periods. An optimal harvesting policy reduces the relative risk of the decisionmaker. Moreover, the effective planning horizon for these problems

appears to be 3-5 years, after which both policy, risk and preferences remain stationary.

The measure of relative risk R_2 can be seen to be almost a measure of elasticity of the present marginal value of a unit of fish. As an optimal policy "smooths out" the supply of fish, the elasticity of the value per unit of fish decreases.

In conclusions, these results suggest that properly assessing attitudes towards risk is more important than choosing an appropriate discount factor when managing a random fishery. Deterministic models that ignore fluctuations in catch, and the effects these fluctuations have on income, can lead to mismanagement of fisheries.

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Table 1. Changes in relative risk aversion with changes in planning horizon length when following an optimal policy.

	$\lambda = 1$	$\lambda = 0.5$	$\lambda = 0.05$
$n = 2$	0.1430	0.0518	0.045
$n = 3$	0.1684	0.303	0.423
$n = 4$	0.1684	0.325	0.423
$n = 5$	0.1684	0.331	0.423
$n = 6$	0.1684	0.331	0.423
$n = 7$	0.1684	0.331	0.423
$n = 8$	0.1684	0.331	0.423
$n = 9$	0.1684	0.331	0.423
$n = 10$	0.1684	0.331	0.423

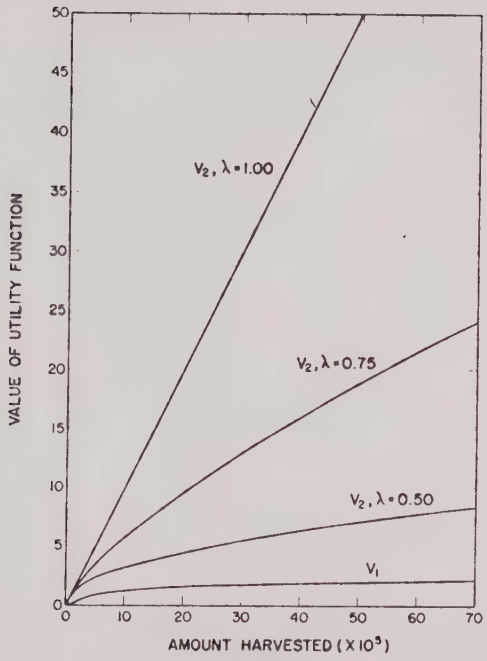

Fig. 1. Graph of the different utilities function.

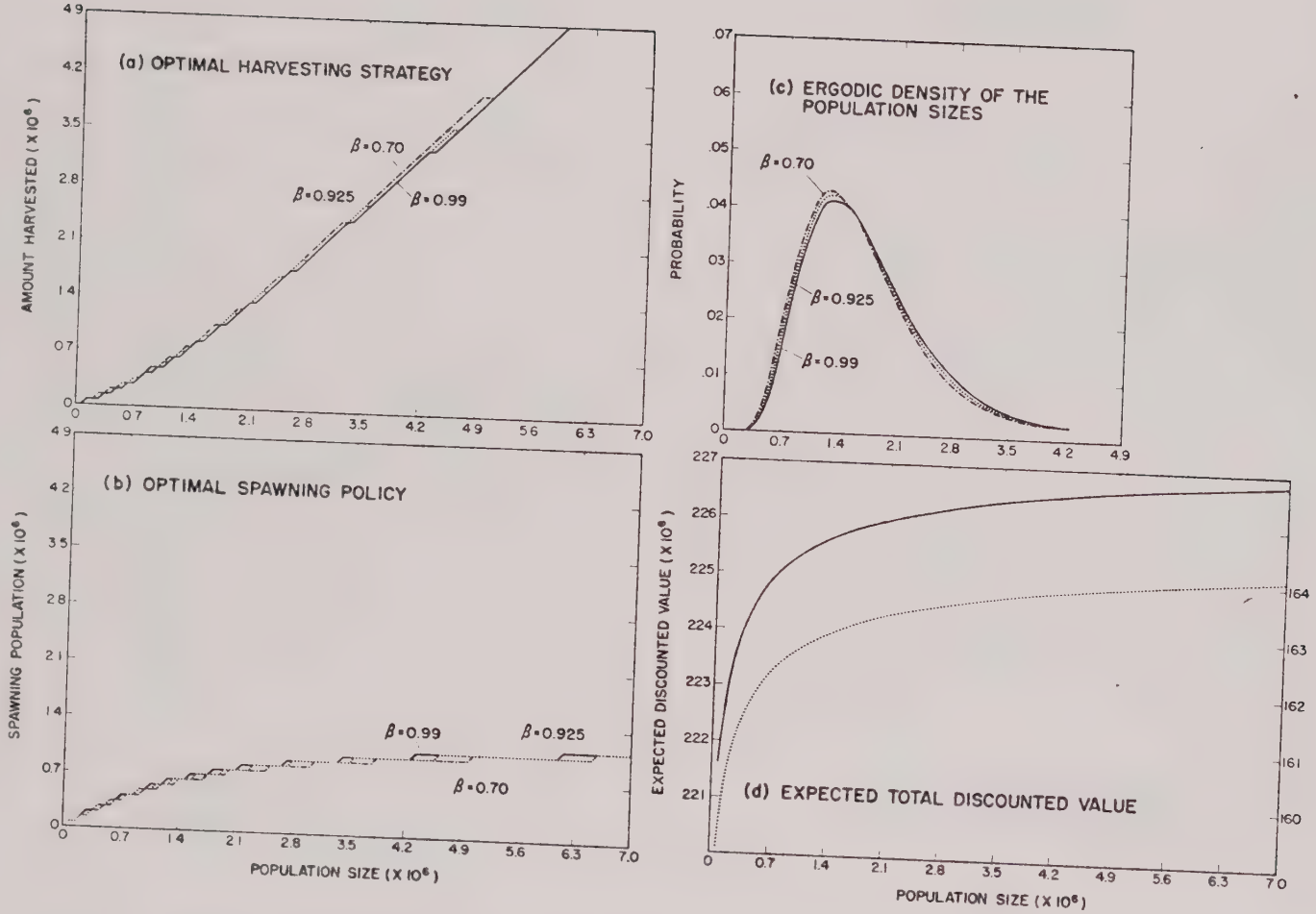

Fig. 2. Effects on an optimal policy and optimal value from varying the discount factor.

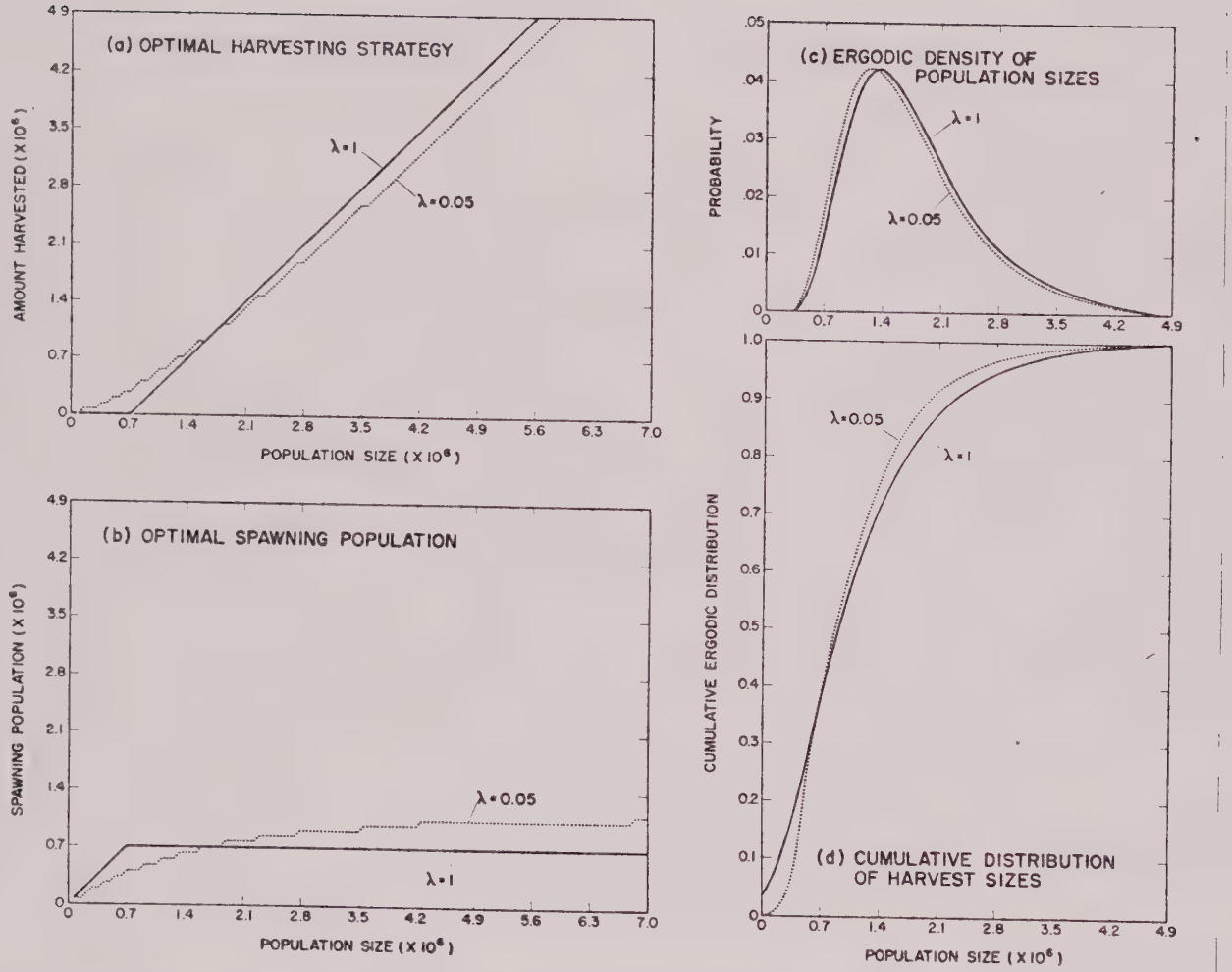

Fig. 3. Effects on an optimal policy and optimal value from varying the degree of risk aversion.

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SUMMARY REPORT OF THE PACIFIC CIGUATERA WORKSHOP HONOLULU, HAWAII, 18-20 MARCH 1981

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The Hawaii Ciguatera Workshop, cosponsored by the Honolulu Laboratory and the University of Hawaii Sea Grant (UHSG), was held at the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Honolulu, Hawaii from March 18 to 20, 1981. Mr. Richard S. Shomura, Honolulu Laboratory Director and Chairman of the workshop, opened the workshop by welcoming all the participants and observers and made a few introductory remarks including the rationale for holding the workshop. The objective of the workshop was to bring together some of the principal, active ciguatera researchers in the Pacific to help develop working hypotheses to guide future research on the ciguatera problem. It is recognized that the ultimate goal of ciguatera research is to fully understand the mechanism underlying the origin and transfer of the toxin(s) in the ecosystem and to develop corrective measures to provide nontoxic fish for human consumption.

The workshop agenda (Appendix 1) included the consideration of four broad areas or aspects of ciguatera research: toxins, the detection of toxins, the medical/pharmacological aspects of ciguatera, and the ecological aspects. Seven background papers were assembled for the workshop (Appendix 2) and nine working papers which described ongoing ciguatera research in the Pacific were presented (Appendix 3). In addition to the oral presentations on ciguatera research in the Pacific, presentations were made on the results of the recent World Health Organization meeting on ciguatera held in Noumea, New Caledonia, and on the status of ongoing ciguatera research in the southeastern United States. The workshop participants and observers are listed in Appendix 4.

TOXINS (WP/2, WP/6)

The discussion on toxins covered the topics of the chemical and molecular structure of ciguatoxin and other toxins and the origin of the toxins. The problem of solving the molecular structure of ciguatoxin has been hampered by the lack of an adequate supply of pure toxin for analysis. The toxin is diffusely distributed in minute amounts in the flesh and viscera of fishes so large amounts of toxic fish are needed to extract the toxin in a complex purification procedure. Dr. Paul Scheuer of the University of Hawaii (UH) now has 0.9 mg of ciguatoxin and Dr. Takeshi Yasumoto of Tohoku University, Sendai, Japan, has 0.4 mg. Although the analytic methods used to determine the molecular structure of the toxin is basically non-destructive, minute amounts of the toxin are lost in the analyses. Dr. Scheuer's 0.9 mg of ciguatoxin is presently at the California Institute of Technology for analysis. The basic, empirical formula of ciguatoxin, $(C_{35}\ H_{65}\ NO_8)_n$, has been known for some time. Although the molecular structure of ciguatoxin is not completely known, it is believed that the problem will be solved when more pure toxin becomes available. In this regard, it was announced that the UH will soon be acquiring a 300 MHz Nuclear Magnetic Resonance Spectrometer for the analysis of the molecular structure of complex compounds. This will greatly increase the instrument time available for the analysis of the molecular structure of ciguatoxin.

A breakthrough in ciguatera research occurred within the past 5 years when the source of ciguatoxin in the coral reef ecosystem was determined to be a benthic dinoflagellate, Gambierdiscus toxicus, a microscopic unicellular alga that grows primarily as an epiphyte on certain seaweeds on reef flats. This same species has been found near the Hawaii Institute of Marine Biology (HIMB)

in Kaneohe Bay and at other scattered locations around the island of Oahu. The results of experiments conducted at HIMB to determine the factors controlling toxin production, growth rate, and yields of laboratory cultures of the HIMB strain of G. toxicus were discussed. A problem in the research on culturing G. toxicus is the tremendous variability in the levels and kinds of toxins present in the cultures.

Elsewhere in the Pacific, the possible sources of secondary toxins have also been investigated. In addition to maitotoxin, the presence of secondary toxins have often been detected in the viscera of herbivorous fishes and it can be hypothesized that these secondary toxins, like ciguatoxin, originate from other benthic dinoflagellates. It was found that several species of dinoflagellates found growing with G. toxicus also produced toxins that were lethal to mice. Of interest are two fat soluble toxins of Prorocentrum lima, PL toxins I and II, which are practically indistinguishable in chromatographic properties from scaritoxin and ciguatoxin, respectively. A chemical and spectral analysis of PL toxin II showed that it is identical with okadaic acid, the cytotoxic component of a sponge.

DETECTION (WP/4, BP/2, BP/3, BP/6)

The early tests for ciguatoxin have been bioassays in animals such as mouse, cat, and mongoose. Among the shortcomings of these bioassays are that they are subjective and, in the case of the mongoose, the test animals are obtained from the wild and, therefore, are not homogeneous. A breakthrough in testing for ciguatoxin occurred with the development of a radioimmunoassay (RIA) for the direct examination of fish tissues for toxin. The advantages of the RIA are that it is simple and practical, relatively specific, and sensitive. One of the objectives of current research is to evaluate the RIA procedure for ciguatoxin based on two approaches: 1) identifying the reactive factor in the sheep anti-ciguatoxin serum used in the RIA, and 2) assessing the RIA procedure on fishes from clinically defined and documented cases of ciguatera intoxication and comparing results with those from nontoxic fish of the same species. The RIA results are also being evaluated by supportive bioassays, the mouse bioassay, and the guinea pig atrium assay.

There was much discussion on the technical aspects of the immunological reactions of the RIA procedure including questions on dose responses, extracts, and homogenates versus solids. It was pointed out that the whole basis of the RIA procedure is the assumption that ciguatoxin, being a lipid, is bound on the membrane surface or cells so that it can be detected by an antibody. Some of the difficulties associated with the RIA procedure is 1) sampling, i.e., there is uncertainty in the distribution of ciguatoxin in the fish flesh, 2) the possibility of false positives occurring in the RIA test and, 3) reproducibility owing to the fact that tissues are used and even within close proximity "hot spots" of ciguatoxin may vary.

Beginning in April 1979, at the request of the Hawaiian fishing industry and in cooperation with the Honolulu Laboratory, the RIA test was used to screen commercially landed kahala, Seriola dumerili, for ciguatoxin. The testing program made possible the marketing of large numbers of kahala larger than 20 pounds which, before the testing started, were ordinarily not marketed in the belief that large fish were more likely to be toxic. The most

significant result of the testing program has been the absence of any reported ciguatera cases from marketed RIA-negative kahala.

Mouse bioassays and guinea pig atrium assays have been used to evaluate the RIA procedure. Although the number of test samples is small, the data suggest direct correlations among the three assays. It was noted that ciguatoxin causes an initial massive release of neuroepinephrine in guinea pig atrium. However, one of the clinical symptoms of ciguatera intoxication in humans is reduced cardiac activity. In light of the effect of ciguatoxin on guinea pig atria, the question was posed regarding the effect of ciguatoxin on humans in the early stage of ciguatera intoxication.

Research is also underway to develop an enzyme-linked immunosorbent assay (ELISA) for ciguatoxin. ELISA is simpler and more rapid and unlike the RIA procedure, is not dependent on the use of radioisotopes. Current research on ELISA includes the establishment of toxicity ranges based on absorbence values of samples from clinically documented tissues from ciguatera intoxications and nontoxic tissues. A comparison of RIA and ELISA tests on kahala indicated that ELISA gave a lower rejection rate, which may be more realistic in light of the incidence of reported ciguatera intoxications by kahala in the past.

MEDICAL/PHARMACOLOGY (WP/7, WP/8, WP/9)

This section of the workshop dealt primarily with the public health aspect of ciguatera intoxication. The results of a study to determine the effect of ciguatera on the overall health of Pacific islands populations and how it has affected the utilization of marine resources were discussed. The study was an extensive comparative investigation of the perceived distribution and occurrence of ciguatera in the late 1970s, folk beliefs as to the etiology of the disease, and other aspects of the health and resource problems stemming from ciguatera. Statistics on ciguatera morbidity rates from the South Pacific Commission Health and Epidemiological Information Service (SEPHIS) area were presented. In 1978 the mean repoted ciguatera morbidity rate for the area (excluding Papua New Guinea) was 12.01/10,000. The actual morbidity rate is undoubtedly considerably higher.

A summary of ciguatera intoxication in Hawaii covering a period from 1900-80 was presented. It was noted that cases of ciguatera intoxication were higher in the spring and autumn and that more patients rather than physicians are apt to report ciguatera poisonings. It was further noted that a 25% reporting rate is considered good.

A detailed account of the fatality caused by Marquesan sardine, Sardinella marquesensis, on Kauai in 1978 was also presented. Clinical data from this case were remarkably similar to what would be expected from a severe form of ciguatera intoxication, and it was suggested that clupeoid poisoning should not be excluded from the concern of those doing research on ciguatera poisoning. However, other workshop participants noted that clupeoid poisoning may be more closely related to paralytic shellfish poisoning (PSP) in ecological terms.

ECOLOGY (WP/1, WP/3, WP/5, WP/6, BP/1, BP/4, BP/5, BP/7)

Based on the correlation of the population density of G. toxicus with epidemiological information, the endemicity of ciguatera in various locations

in the Pacific was discussed. The results of surveys showed that the density of the G. toxicus population was correlated with fish toxicity. These results suggest that toxicity in any area can be predicted by the density of G. toxicus. Another possibility of a monitoring system for ciguatera is the assessment of the toxicity of fish livers. It has been shown that fish livers show far less variability in toxicity than the flesh of fishes.

The results of a study on the distribution of G. toxicus in French Polynesia (Tahiti and Gambier Island), New Caledonia, Guam, and Okinawa were also presented, including the effect of certain environmental factors on the density of G. toxicus. Temperature is not an important factor in the density of G. toxicus. However, salinity and light intensity appear to be important. Iron was not important in the growth of G. toxicus but phosphates significantly increased the growth.

Development of the RIA procedure made possible large-scale testing of fishes for ciguatoxin. As part of the cooperative survey of the marine resources in the Northwestern Hawaiian Islands (NWHI), the Honolulu Laboratory and the Hawaii Division of Fish and Game (HDFG) have been sampling inshore and nearshore fishes to determine the distribution of ciguatoxic fishes.

The Honolulu Laboratory's results of tests for ciguatoxin on fish and shellfish collected in the NWHI, Midway Islands, American Samoa and Western Samoa, and Guam and the Northern Mariana Islands were presented. The overall rejection (positive and borderline toxicity levels) rate was 15% for NWHI, 39% for Midway, 19% for American Samoa and Western Samoa, and 4% for Guam and the Northern Mariana Islands.

Flesh samples from fishes are obtained from the dorsal anterior region (A), ventral abdominal region (B), and the anal region (E). It was pointed out that there was no clear trend as to where (sites A, B, or E) the toxin is concentrated in the fish. The results were not only variable among species, but also between sexes. The results to date showed also that toxicity was not related to size or sex.

The results obtained by the HDFG indicate that fishes in the NWHI were relatively more toxic (in terms of numbers rejected in the RIA test) in the summers of 1977 and 1978 than in 1979 and 1980. In 1980 the nearshore fishes were more toxic in the fall than in the summer. Based on these results, it was suggested that the occurrence of ciguatoxic fishes appear to be cyclical. The feeding habits, distribution, and abundance of the fishes sampled were also described.

Also, some anomalous results in the HDFG data and the Honolulu Laboratory data were evident. In sampling around Midway in 1980, the Honolulu Laboratory samples indicated an overall high rejection rate for fishes caught from September 30 to October 4, whereas the HDFG samples collected around the same period showed a relatively low rejection rate.

The results of an analysis of data from the kahala sampling program between April 1979 and December 1980 were also discussed. The mean quarterly RIA scores showed a general trend of a decline in RIA scores from the second quarter of 1979 to a low at the end of 1979/beginning of 1980 and a subsequent increase in RIA scores through 1980. The trend was consistent for sampling

sites A, B, and E, for geographical origin of the fish (NWHI, Oahu, Penguin Bank, and Hawaii), and for both sexes. The correlation of RIA between sampling sites was high: (AB) = 0.74, (AE) = 0.69, and (BE) = 0.70. Also, the variation in RIA scores from two replicates from each sampling site (A, B, and E) was no greater than the variation among sampling sites A, B, and E. Other results indicated that: there was no relationship between kahala weight and RIA scores, and that sampling site B or E would be the best single site to sample for maximum RIA values.

Color slides of the various fish species implicated in ciguatera intoxication were shown and the distribution, food habits, and habitat of these fishes were described. The species that have caused ciguatera are shore fishes associated with reefs, are bottom-dwelling, but they may also be semipelagic open-water forms that range into the reef habitat to feed. They may be carnivorous or they may be benthic algal or detrital feeders. The carnivores that prey heavily on reef fishes are the most prone to be toxic whereas those that feed primarily on benthic crustaceans tend to be least toxic. The moray eel, Lycodontis (= Gymnothorax) javanicus, is highly toxic.

Other ecological aspects of ciguatera were also discussed. Young and old Hawaiian monk seals, Monachus schauinslandi, in the NWHI suffered high mortality in 1978. It was speculated that ciguatera intoxication could have been the cause of the mortality. In connection with this, the results of experiments where elephant seals, Mirounga angustirostris, were fed moray eels caught in the NWHI were described. Elephant seals were found to be highly susceptible to ciguatera intoxication.

RECOMMENDATIONS

The workshop identified three general objectives or goals for future ciguatera research. The first goal is to obtain an understanding of the factors or mechanisms triggering the chain of events leading ultimately to potential outbreaks of ciguatera intoxication so that these events could be predicted. The second goal is to elucidate the pharmacological aspects of ciguatera and to develop a viable treatment for ciguatera intoxication. The third goal is to develop and disseminate a quick and reliable field test to screen marine organisms for ciguatoxin and related toxins.

Several general areas of research were recommended to achieve the first objective:

1. Determine baseline conditions in (a) areas with no previous history of ciguatera outbreaks and (b) areas that could potentially produce ciguatera outbreaks. Related to this is the determination and verification of factors causing blooms of Gambierdiscus toxicus and the comparison of environmental conditions in areas containing and devoid of dinoflagellate blooms.

2. Verify the source of ciguatoxin in the reef ecosystem; determine the rate of toxin production from culture experiments and determine factors that influence the growth of toxin-producing dinoflagellates. Determine the source (cysts?) of dinoflagellate blooms.

3. Conduct field and laboratory studies to determine the transfer and metabolism of ciguatoxin in the food chain.

4. Determine the effects of ciguatoxin on fish including its toxicity to fish and its influence on growth rates; conduct experiments to determine if ciguatoxin is accumulated in fish or excreted and whether it would be possible to predict time/area fish toxicity based on dates/areas of dinoflagellate blooms; determine why some species are more toxic than others including a quantitative analysis of toxicity levels by species, size, and area, and compare findings with the food chain understanding; and determine whether crustaceans and molluscs in areas of dinoflagellate blooms are toxic.

5. Evaluate the ELISA technique for field work.

Research activities recommended to achieve the second goal were:

1. Determine source of toxin by locating toxic areas, e.g., by public health follow-ups, search for alternate source of ciguatoxin by bio-testing for possible new sources. A related activity is to determine factors that make dinoflagellates toxic.

2. Collect toxic fishes including moray eels, RIA-rejected kahala, and other species and develop cultures of Gambierdiscus toxicus to extract the crude toxins.

3. Assemble hardware and manpower to extract and purify toxins for experiments to a) compare toxin from moray eel with toxins from other species, b) determine the molecular structure of ciguatoxin and other toxins, and c) determine the metabolic pathways and target tissues/organs in tests on mice and other animals and muscle tissues, c) investigate the pharmacology of ciguatoxin to determine metabolic pathways and target tissues/organs, in tests on mice and other animals, and d) determine the efficacy of off-the-shelf drugs for the treatment of ciguatera in test animals and in clinical trials.

Research activities recommended for the third goal were:

Develop usable ELISA test for ciguatoxin and 1) improve specificity of ELISA test to sort out other toxins (scaritoxin, maitotoxin, okadaic acid) and 2) adapt ELISA procedure for a "dip stick" test.

APPENDIX 1

AGENDA

1. Introduction (R. Shomura)

    1.1 Participants
    1.2 Objectives of workshop

2. Report of SPC ciguatera meeting (A. Banner)

3. Toxins

    3.1. Chemical composition (P. Scheuer)
    3.2. Dinoflagellates (T. Yasumoto, N. Withers)

4. Detection

    4.1. RIA (Y. Hokama, L. Kimura)
    4.2 ELISA (Y. Hokama, L. Kimura)
    4.3 Muscle tests (J. Miyahara)

5. Medical/Pharmacology

    5.1. Case histories--Hawaii (M. Sugi)
    5.2 Case histories--Other Pacific areas (N. Lewis)
    5.3 Pharmacological (J. Miyahara)

6. Ecology

    6.1. Elaborators (T. Yasumoto, N. Withers)
    6.2. Fishes

        6.2.1. NWHI fishes (Honolulu Laboratory, Hawaii Division of Fish and Game)
        6.2.2. Kahala (Honolulu Laboratory)
        6.2.3. Other areas--American Samoa, western Pacific (Honolulu Laboratory)

    6.3. Other animals

        6.3.1. Hawaiian monk seal (Honolulu Laboratory)
        6.3.2. Others--birds, turtles (open)

APPENDIX 2

LIST OF BACKGROUND PAPERS

BP/1 Adachi, Rokuro, and Yasuwo Fukuyo.
1979. The thecal structure of a marine toxic dinoflagellate, Gambierdiscus toxicus gen. et sp. nov. collected in a ciguatera-endemic area. Bull. Jpn. Soc. Sci. Fish. 45:67-71.

BP/2 Hokama, Y., A. H. Banner, and D. B. Boyland.
1977. A radioimmunoassay for the detection of ciguatoxin. Toxicon 15:317-325.

BP/3 Hokama, Y., L. H. Kimura, and J. T. Miyahara.
In press. Immunological approaches to understanding marine toxins. Proceedings of the Sixth Food and Drug Administration Science Symposium on "Aquaculture - Public Health, Regulatory and Management Aspects," February 12-14, 1980, New Orleans, Louisiana (Office of Health Affairs, FDA).

BP/4 Humphreys, Robert L., Jr.
1980. Feeding habits of the kahala, Seriola dumerili, in the Hawaiian Archipelago. In Richard W. Grigg and Rose T. Pfund (editors), Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, April 24-25, 1980, University of Hawaii, Honolulu, Hawaii. Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-80-04, p. 233-240.

BP/5 Ito, Bernard M., and Richard N. Uchida.
1980. Results of ciguatera analysis of fishes in the Northwestern Hawaiian Islands. In Richard W. Grigg and Rose T. Pfund (editors), Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, April 24-25, 1980, University of Hawaii, Honolulu, Hawaii. Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-80-04, p. 81-89.

BP/6 Miyahara, J. T., C. K. Akau, and T. Yasumoto.
1979. Effects of ciguatoxin and maitotoxin on the isolated guinea pig atria. Res. Commun. Chem. Pathol. Pharmacol. 25:177-180.

BP/7 Randall, John E.
1980. A survey of ciguatera at Enewetak and Bikini, Marshall Islands, with notes on the systematics and food habits of ciguatoxic fishes. Fish. Bull., U.S. 78:201-249

APPENDIX 3

LIST OF WORKING PAPERS

WP/1 Polovina, Jeffrey J., and Bernard M. Ito.
An analysis of data from the kahala ciguatera sampling program, April 1979-December 1980.

WP/2 Withers, Nancy.
Pacific ciguatera.

WP/3 Uchida, Richard N., Bernard M. Ito, Paul M. Shiota, Darryl T. Tagami, Karen P. Wendel, Victor A. Honda, and Michael P. Seki.
Status of the Honolulu Laboratory ciguatera research on fishes of the Northwestern Hawaiian Islands, American Samoa, Western Samoa, Guam, and the Northern Mariana Islands.

WP/4 Hokama, Y., L. Kimura, and J. Miyahara.
Status report on detection methods for ciguatoxin.

WP/5 Okamoto, Henry.
Status report of ciguatera research in the Northwestern Hawaiian Islands by DLNR, Division of Fish and Game.

WP/6 Yasumoto, Takeshi, Yasukatsu Oshima, Akio Inoue, Yasuwo Fukuyo, and Takako Harada.
Studies on ciguatera.

WP/7 Kubota, Wilbert.
Ciguatera fish poisoning cases: A summary from 1900 - December 1980.

WP/8 Lewis, Nancy Davis.
Ciguatera morbidity in the island Pacific.

WP/9 Melton, Robert J.
Summary of data on fatal case of fish poisoning associated with Marquesan sardine, Kauai, 1978.

APPENDIX 4

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Southwest Fisheries Center Administrative Report H-81-3

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National Marine Fisheries Service
2570 Dole Street
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A PROCEDURE TO CLASSIFY SPINY LOBSTERS AS LEGAL OR SUBLEGAL BASED ON TAIL WIDTHS

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June 1981

Based on conservation and management considerations the Western Pacific Regional Fishery Management Council (WPRFMC) has decided to prohibit the harvesting of spiny lobsters with carapace lengths less than 7.7 cm. Lobsters with carapace lengths greater than or equal to 7.7 cm are termed legal sized or legal and those with carapace length less than 7.7 are termed sublegal. Many lobster vessels freeze the lobster tails at sea and land only the frozen tails. Thus for purposes of onshore enforcement, it is necessary to have a procedure to determine whether a lobster was of legal or sublegal size based only on tail measurements. Using data collected on the RV Townsend Cromwell a discriminant analysis was used to develop such a classification procedure.

DATA

Two data sets were used for the discriminant analysis. One data set consists of carapace length, tail width, and tail length measurements on 1,652 live spiny lobsters trapped over the past 4 years throughout the Northwestern Hawaiian Islands (NWHI). In this data set 15% of the lobsters are sublegal and 85% are legal sized (Table 1). The second data set consist of carapace length and tail width measurements on 116 live lobsters which were then "tailed" and frozen. After freezing, the tail width of the frozen tails were recorded. These lobsters were trapped at Necker and Maro banks during April 1981 and contained 53% sublegals and 47% legals (Table 2).

The tail width measurements for both data sets were measured as the distance between the lateral notches on the first tail segment.

ANALYSIS

Discriminant analysis is a statistical procedure which classifies an observed individual in one of a given set of populations. In the present analysis we will use the procedure to classify a lobster as either belonging to one of two populations, sublegal or legal, based on tail measurements.

To apply discriminant analysis the following information is needed:

1) The relative frequency of legal and sublegal lobsters in the trappable population.

Recent size-frequency data from Maro bank show that 25% of the trappable population is sublegal; at Necker bank, 53% of the trappable population is sublegal. As fishing effort continues at Maro the percent of sublegals in the trappable catch will probably increase. As an average estimate of the relative percent of sublegals and legals in the trappable population at the commercially fished banks, the values of 40% sublegal and 60% legal have been chosen.

2) The relative weights for the loss function which measures the loss from misclassifying a sublegal as a legal and the loss from misclassifying a legal as a sublegal.

Based on the assumption that these two types of losses are equal, equal weights are used.

The discriminant analysis procedure now estimates the classification function which is optimum in the sense that it minimizes the probability that a lobster selected at random from the trappable population is incorrectly classified as legal or sublegal. The discriminant analysis was first performed using both tail width and tail length variables. The results showed that tail length did not provide any additional information or improvement in the

classification of a lobster as sublegal or legal over that provided solely by tail width. Application of the BMDP computer program for discriminant analysis to the tail width data results in the following classification rule:

If tail width $\geq$ 5.1 cm, classify the lobster as legal.

If tail width < 5.1 cm, classify the lobster as sublegal.

Based on the sample of 1,652 lobsters this classification procedure correctly classifies 94.9% of the sublegals and 86.8% of the legals. The empirical size-frequency distribution of tail widths can be used to obtain an estimate of the percent of correct classifications for various values of the minimum tail width for legals (Table 3). From Table 3 it can be seen that as the minimum tail width for classification as legal increases, the percent of correct classification for sublegals increase and the percent of correct classification for legals decreases. Based on this table, the probability that a lobster chosen at random from the trappable population is correctly classified is maximal when the minimum tail width for classification as legal lies in the interval between 5.0 and 5.1 cm. This empirical result is in close agreement with our estimate of 5.1 cm obtained from the discriminant analysis.

It should be recalled that the tail width measurements for the 1,652 lobsters used in this analysis were taken on live lobsters. To determine if freezing of the lobster tails has an effect on the tail width, a regression analysis was performed regressing frozen tail width on live tail width based on the set of 116 lobsters for which tail width measurements were taken before and after freezing. The intercept for this regression was set at zero. The estimate of the slope was 1.0036 (standard error = 0.0018, R^2 = 0.999). This regression suggests that there is no appreciable change in tail width due to

freezing and hence a lobster will be classified as legal if the width of the frozen tail is equal to or exceeds 5.1 cm.

Application of this procedure to classify the lobsters from the sample of 116 frozen tails results in correctly classifying 100% of the sublegals and 100% of the legals.

Since discriminant analysis estimates the classification function which maximizes the probability that a lobster chosen at random from the trappable population will be correctly classified (as either sublegal or legal) based on the tail width measurement, the classification function will necessarily be sensitive to the proportion of sublegals and legals in the trappable population. Table 4 presents the minimum tail width for classification as legal sized and the percent of correct classification for three distributions of sublegals and legals in the trappable population. As the proportion of legals in the trappable population increases it becomes more important to correctly classify the legals and hence the minimum tail width for correct classification decreases. While discriminant analysis is sensitive to changes in the underlying population parameter it is more robust to changes in the sample structure. Table 5 presents the estimates of discriminant analysis for the original sample of 1,652 lobsters and two truncated population derived from this sample obtained by removing all lobsters greater than 10 and 9.25 cm, respectively.

Table 1.--Size frequency of carapace length for a sample of 1,652 lobsters from the NWHI in 5-mm size categories.

Carapace length (mm)	Frequency (percent)
65-69	0.5
70-74	4.4
75-79	10.3
80-84	18.8
85-89	19.9
90-94	15.2
95-99	10.2
100-104	8.5
105-109	5.0
110-114	4.0
115-119	2.3
120-124	0.8

Table 2.--Size frequency of carapace length for a sample of 116 lobsters from Necker and Maro banks.

Carapace length (mm)	Frequency (percent)
65-69	3.9
70-74	17.6
75-79	25.5
80-84	2.9
85-89	12.7
90-94	13.7
95-99	9.8
100-104	6.9
105-109	3.9
110-114	1.0
115-120	2.0

Table 3.--Percent of sublegals and legals correctly classified as a function of minimum tail width based on the empirical size-frequency distribution.

Minimum tail width for classification as legal sized (cm)	Percent of sublegal correctly classified[1]	Percent of legals correctly classified[1]	Probability of correctly classifying a lobster chosen at random[2]
4.7	40.5	99.6	0.76
4.8	62.3	97.9	0.84
4.9	79.8	94.3	0.89
5.0	87.5	92.4	0.90
5.1	95.3	86.2	0.90
5.2	99.4	79.6	0.88

[1]Estimated from a sample of 1,652 lobsters.

[2]Based on the relative frequency of sublegals as 0.4 and legals as 0.6 in the trappable population.

Table 4.--Discriminant analysis for several different frequencies of sublegals and legals in the trappable population.

Population frequency		Minimum tail width for classification as legal (cm)	Percent of correct classification	
Percent sublegal	Percent legal		Sublegal	Legal
50	50	5.2	99.2	80.2
40	60	5.1	94.9	86.8
25	75	5.0	77.8	96.5

Table 5.--Discriminant analysis for samples with several different ranges of carapace length.

Carapace length range in sample (cm)		Minimum tail width for classification as legal (cm)	Percent correctly classified	
Minimum	Maximum		Sublegal	Legal
6.5	12.4	5.1	94.9	86.8
6.5	10.0	5.0	94.6	85.3
6.5	9.25	5.0	86.8	88.9

Table 5.--Discriminant analysis for samples with several different ranges of carapace length.

Carapace length range in sample (cm)		Minimum tail width for classification as legal (cm)	Percent correctly classified	
Minimum	Maximum		Sublegal	Legal
6.5	12.4	5.1	94.9	86.8
6.5	10.0	5.0	94.6	85.3
6.5	9.25	5.0	86.8	88.9

SEAMOUNT FISHERY, FOREIGN VESSEL OBSERVER REPORT

ASO MARU (June 9-19, 1981)

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24 1981

National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

By

Nathaniel T. Shippen
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96812

July 1981

ASO MARU

Vessel Statistics

Permit number:	JA-81-0288-B
Length:	90.45 m
Gross tonnage:	3,608.29
Net tonnage:	1,968.81
Width:	16.0 m
Draft:	9.80 m
Engine type:	Diesel
Horsepower:	3,900
Hull number:	96090
Registration number:	TOEN-701
Company-owner:	Nippon Suisan, Ltd.
Vessel type:	Independent stern trawler
Year commissioned:	1964
Home port:	Tobata, Japan

Personnel

Captain:	Mokichi Sase
Number of officers:	9
Number of crew:	28
Processing:	13
Total ship complement:	50
Experience in seamount fishery:	None

Area of Operation

Seamounts	Latitude	Longitude
Northwest Hancock	30°15'N-30°17'N	178°42'N-178°43'E
Southeast Hancock	29°47'N-29°49'N	179°03'E-179°05'E
K Bank	29°40'N	179°22'E

TRAWL RESULTS

Target Species

Common names:	Armorhead, boarfish
Japanese name:	Kusakari tsubodai
Scientific name:	*Pentaceros richardsoni*
Species code:	080
Common name:	Alfonsin
Japanese name:	Kinmedai
Scientific name:	*Beryx splendens*
Species code:	081

On May 22, 1981 the Nippon Suisan, Ltd. of Japan notified the National Marine Fisheries Service (NMFS) Honolulu Laboratory that two of Nippon Suisan's trawlers would be fishing the Hancock Seamounts during the 1981 trawl season. The first of these trawlers, Aso Maru, intended to begin fishing there on June 10. Nippon Suisan planned that the ship would fish within the U.S. Fishery Conservation Zone (FCZ) for about 10 days.

As a member of the NMFS Honolulu Laboratory Foreign Vessel Observer Program, I was assigned to monitor the Aso Maru's fishing operations for the time the vessel was within U.S. waters. I boarded the Aso Maru at Midway Island on June 9. The ship began fishing on June 10 and trawled the Hancock Seamounts until June 18, when the total catch exceeded the company-assigned quota of 400 metric tons (MT). The Aso Maru then left the FCS, after disembarking me at Midway on June 19.

Trawl Gear

See Figure 1 for dimensions.

The ship made 25 hauls at the Southeast Hancock Seamount. The average trawl haul was 90 minutes. Nineteen trawl hauls were made at the Northwest Hancock Seamount averaging 99 minutes per haul. The five trawl hauls made at K Bank averaged 14 minutes per haul.

Out of a total of 418.2 MT caught at the Hancock Seamounts during June 10-18, 389.4 MT (93.1%) were armorhead, 19.9 MT (4.8%) were alfonsin, and 8.9 MT (2.1%) were other species (Table 1).

SAMPLING RESULTS

1. Pelagic armorhead, Pentaceros richardsoni

Morphology. I divided the armorheads into three body types: fat, lean, and medium.

a. Southeast Hancock Seamount

Overall

Number measured: 207

Average length: 302 mm Range: 259-331 mm
Average weight: 0.50 kg

Number weighed and sexed: 49

Sex ratio: Male 34 (69%)
Female 15 (31%)

Fat Type 59%

Number measured: 93

Average length: 307 mm Range: 276-331 mm

Lean Type 24%

Number measured: 38

Average length: 290 mm Range: 259-322 mm

Medium Type 17%

Number measured: 27

Average length: 302 mm Range: 265-325 mm

b. Northwest Hancock Seamount

Overall

Number measured: 158

Average length: 301 mm Range: 250-326 mm
Average weight: 0.53 kg

Number weighed and sexed: 46

Sex ratio: Male 14 (30%)
Female 32 (70%)

Fat Type 60%

Number measured: 95

Average length: 304 mm Range: 265-326 mm
Average weight: 0.54 kg

Number weighed and sexed: 36

Sex ratio: Male 10 (28%)
Female 26 (72%)

Lean Type 25%

Number measured: 39

Average length: 294 mm Range: 250-320 mm
Average weight: 0.40 kg

Number weighed and sexed: 3

Sex ratio: Male 1 (33%)
Female 2 (67%)

Medium Type 15%

Number measured: 24

Average length: 302 mm Range: 255-326 mm
Average weight: 0.55 kg

Number weighed and sexed: 7

Sex ratio: Male 3 (43%)
Female 4 (57%)

c. K Bank

Overall

Number measured: 73

Average length: 302 mm Range: 270-334 mm

2. Alfonsin, Beryx splendens (Note: Many were immature and could not be sexed.)

a. Southeast Hancock Seamount

Number measured: 127

Average length: 186 mm Range: 145-390 mm
Average weight: 0.56 kg

Number weighed and sexed: 11

Sex ratio: Male 4 (36%)
Female 7 (64%)

b. Northwest Hancock Seamount

Number measured: 37

Average length: 227 mm Range: 150-371 mm
Average weight: 0.15 kg

Number weighed and sexed: 19

Sex ratio:		
	Male	1 (5%)
	Female	0
	Unidentified	18 (95%)

c. K Bank

No alfonsin were sampled for length from K Bank.

3. Other commercial species

The only nontarget species that I saw being frozen was Erythrocles schlegelii. All other species were used for fish meal.

4. Only one piece of dead coral (weighing 0.1 kg) was incidentally dredged up during my stay on the vessel. Based on this, I estimated that 20 kg of coral were incidentally dredged up during the entire cruise, but this estimate is probably a gross exaggeration of the actual catch.

SHIPBOARD PRODUCTS AND RECOVERY RATIOS (VESSEL ESTIMATES)

Species Product

1. Armorhead

Frozen fish (headed and gutted)	222.6 MT
Fish meal and oil	See below

The product recovery ratio is estimated to be 56-58.5% of the fish, depending on size (more is recovered from larger fish).

2. Alfonsin

Frozen fish (headed and gutted)	0.5 MT
Fish meal and oil	See below

The recovery ratio for headed and gutted alfonsin is estimated to be 52%.

3. Other species

Frozen whole fish	0.3 MT
Frozen fish (headed and gutted)	1.9 MT
Frozen fish (fillets)	0.2 MT
Fish meal and oil	See below

The recovery ratio for headed and gutted fish overall is estimated to be 55-58%, again depending on the size of the fish.

By-Products

All fish or parts of fish that were unsuitable for freezing (heads, viscera, small or badly damaged fish) were converted to fish meal and fish oil. No records were kept on the weights of particular species groups that were so utilized. Overall, 27.0 MT of fish meal and 24.3 MT of fish oil were produced.

The overall recovery ratio for fish meal was estimated to be 16%. The fish oil recovery ratio was estimated to be 9-12% for armorhead caught in the summer (8-9% for winter fish). The alfonsin-to-fish oil recovery ratio was estimated at 2.5%.

ITINERARY

June	9	- Departed Honolulu Arrived Midway Embarked Aso Maru
	10	- Began sampling
	17	- Sampling ended
	19	- Disembarked Aso Maru Arrived Midway
	20	- Departed Midway Arrived Honolulu

RECORDS

The following records were kept:

Scientists log
Daily trawl haul form
Species composition from basket samples
Size-frequency log

OBSERVER: Nathaniel T. Shippen, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, Honolulu, Hawaii 96812.

Table 1.--Trawl catch by species and area (in metric tons).

Species	Southeast Hancock Seamount	Northwest Hancock Seamount	K Bank	Total
Armorhead	259.3	118.0	12.1	389.4
Alfonsin	11.2	8.7	0.0	19.9
Others	3.1	5.8	0.0	8.9
Total	273.6	132.5	12.1	418.2

Table 2.--Catch per unit of effort by area and species.

Area	No. hauls	Total minutes* (trawl in water)	Armorhead		Alfonsin		Other species		All species	
			Total catch (kg)	Kg/min	Total catch (kg)	Kg/min	Total catch (kg)	Kg/min	Total catch (kg)	Kg/min
Southeast Hancock Seamount	25	2,250	259,279	115.24	11,247	5.00	3,053	1.36	273,579	121.59
Northwest Hancock Seamount	19	1,885	118,045	62.62	8,654	4.59	5,801	3.08	132,500	70.29
K Bank	5	70	12,074	172.49	0	0	6	0.09	12,080	172.57

*The recorded trawl times include periods when the ship was turning and not over the seamount.

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COMPETITION AND MARKET STRUCTURE IN THE HAWAII FISH INDUSTRY

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July 1981

Prepared for presentation at the American Fisheries Society Conference held in Honolulu, Hawaii July 12-16, 1981.

COMPETITION AND MARKET STRUCTURE IN THE HAWAII FISH INDUSTRY

Michael F. Adams

Industry Economist, Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA

In the last decade considerable doubt has been cast on whether the Hawaii fish industry operates in a competitive manner. The industry has been characterized as being dominated by a handful of fishermen and fish dealers. As a result many people in private business and government feel that a few established firms prevent Hawaii's fish industry from expanding. It is argued that only established fishermen can get a fair price; others are eventually forced out of business; and, wholesalers keep prices to fishermen low and exploit retailers and consumers with high prices. A report by the U.S. Department of Commerce (1971) describes fresh fish wholesalers in Honolulu as cooperating to hold prices down. It further states that individual buyers engage in regular partnerships with advanced agreement to prevent the price of fish from going extremely high. Peterson (1973) reports that barriers to entry exist in the Hawaii fresh fish market created by procurement arrangements between established fishermen and fish dealers. The study also describes how wholesalers meet daily to discuss fish prices. Garrod and Chong (1978) conclude that there is little competition in the fresh fish market. They state that it is obvious that there are colluding tendencies among wholesalers who purchase fresh fish from fishermen. They further report that fishermen collude to determine the offer price. The Garrod and Chong study includes an assessment of the market structure of the fresh fish market in Honolulu. Based on telephone book listings, they identified 27 retailers and 17 wholesalers and described the attrition rate of established firms as low and the mortality high for new firms. They conclude from this and interviews that barriers to entry exist. Finally they conclude that, "The small number of firms...suggest that the phenomenon associated with a highly concentrated market could well exist in the fish wholesale sector. For example, the largest seven wholesalers employ 90% of the total number of employees in fish wholesaling. This may imply the presence of market leadership (price leadership and control of sources of supply) in the fish market. It seems natural for these firms to wield a great amount of market power. It may not even be surprising for them to seek to collude with other dealers."

The objective of this paper is to determine if market structure conditions exist in the Hawaii fish industry which would permit sellers or buyers to exercise market power and create market distortions. The paper is prompted by previous studies which conclude that sellers or buyers of fish in Hawaii collude. Other studies point out the importance of market structure studies for effective public policy (Buchanan, 1969; Lee, 1975; Smith, 1976). They show how policy measures differ with market structure when dealing with market distortions similar to those associated with common property rights in fisheries. A brief overview of the Hawaii fish industry is presented in the next section. The analysis of market structure begins with showing how much of a market is controlled by the largest sellers and buyers. Market structure is

further assessed with information on how freely new firms enter and exit the industry and how well firms are able to maintain their market shares over time.

The bounds of a market structure study are defined by the relevant geographical market and the relevant product line. For fresh fish in Hawaii, Oahu Island is choosen as the relevant geographical market. Only small amounts of fresh fish are imported from foreign countries or exported. The same is true for interstate shipments. Interisland shipments are small relative to the Oahu Island market. The product lines for such a study are usually based on how different products are substitutable in production and consumption. Perfect substitute products can be aggregated. Two types of fresh fish of major commercial importance in Hawaii fisheries are aku (skipjack tuna) and ahi (yellowfin and bigeye tunas). Two species are combined as ahi because there is little distinction made between them in the market. A third species group combines aku and ahi with albacore and kawakawa (bonito) to make up a product line referred to as all tunas. Bottom fish make up a fourth product line which is composed of the following species identified by their common Hawaiian name: uku, ulua, wekeula, gindai, hapuupuu, kahala, lehi, nohu, opakapaka, ehu, kalikali, and onaga. These species are considered close substitutes by consumers. Finally, all species of marine fish consumed fresh, including crustaceans, are combined to make up a fifth species group. This last product line assumes that consumers demand fresh seafood as a unique source of protein which has no perfect substitutes. It furthermore assumes that fishermen have the technology to easily move between fisheries as cost and price conditions change.

The data used in the study were collected from fishermen, wholesalers, and retailers. In some cases collection of the data was facilitated by cooperatives or fish agents who conducted sales or purchase for a number of fishermen and wholesalers. Records for individual transactions were collected and aggregated annually by selling and buying firm, and by species group. To determine how representative the recorded data are, the collected records were compared to independent reports made by fishermen to the State of Hawaii, Division of Fish and Game. Table 1 reconciles the difference between the fish sale reports of fishermen to the State and the recorded purchases collected for this study. Since fishermen do not report whether their catch is sold to the fresh fish market or to processors, I combine purchases of processors with the purchases for the fresh fish market. In 1977 the State Division of Fish and Game received fish landing reports for Oahu Island showing $6,663,000 of sales. In addition, $859,000 of wholesale fish sales on Oahu Island resulted from shipments from the surrounding Hawaiian Islands. Total sales on Oahu Island amounted to $7,522,000. For the same year, the data collection efforts of the National Marine Fisheries Service (NMFS), Honolulu Laboratory revealed total purchases of $7,491,000, which apparently missed about $31,000 of transactions. More than 90% of the total purchases were made for the fresh fish market. Purchases made for canned fish will not be included in this study. For 3 of the 8 years, recorded purchases were greater than the reports to the State Division of Fish and Game. These years are reconciled with landings which were apparently not reported. However, among the possibilities, the difference could be the result of inaccurate counts of the total interisland shipments.

Table 1.--Annual reconciliation of fish sales and purchases for all species in the Oahu Island wholesale fresh fish and processed fish market, 1970-77.

($1,000)

Year	Sales reported to State Division of Fish and Game	Shipments from outer islands	Not reported	Total	Purchases recorded by wholesalers, retailers, and processors	Not recorded	Total
1970	3,116	33	78	3,227	3,227	--	3,227
1971	4,080	30	--	4,110	4,029	81	4,110
1972	4,589	70	--	4,659	4,557	102	4,659
1973	4,796	99	--	4,895	4,681	214	4,895
1974	4,296	307	102	4,705	4,705	--	4,705
1975	4,063	626	56	4,745	4,745	--	4,745
1976	6,237	550	--	6,787	6,602	185	6,787
1977	6,663	859	--	7,522	7,491	31	7,522

Figure 1 shows the three major levels of transactions in the distribution of fish for the fresh fish market on Oahu Island. When wholesalers are vertically integrated to represent fishermen at the ex-vessel level and also to make retail sales, it creates a maze of interactions in the market. Fishermen contribute to the maze by bypassing wholesalers and retailers to sell directly to consumers. On the other hand, retailers may circumvent wholesalers by purchasing directly from the fishermen. In 1980 the NMFS Honolulu Laboratory interviewed 108 wholesalers to determine in part how fresh fish sales were distributed in Hawaii. The results show that about 14% of ex-vessel sales go to retailers. The remainder, fishermen either sell to wholesalers (50%) or are represented in the Oahu Island market by wholesalers (35%). About 98% of final purchases are made from retailers with only small amounts coming directly from wholesalers and fishermen. In all of this, two levels of wholesale transactions can be identified. It is the first level of wholesale transactions that is the interest of this study. Besides fishermen, sellers at the first level will include wholesalers in the Oahu Island market who represent hundreds of fishermen from the outer islands and some on Oahu Island. Buyers at the first level are made up of wholesalers and retailers.

The degree of specialization of sellers and buyers is described in Figure 2 for the year 1976. In 1976 there were a total of 315 sellers and 123 buyers of fresh fish at the first wholesale level. Of the sellers, 67% dealt in tuna and 32% in bottom fish. About 16% specialized exclusively in tuna. Less specialized, 18% sold tuna, bottom fish, and other species. Associated with each group of sellers is a share of total sales. The 20% of sellers who specialized in fish other than tunas and bottom fish accounted for only 1% of total sales. On the buyers side we see that 32% of the firms, those specializing in tuna, only accounted for 2% of total purchases. In contrast, 90% of all purchases were made by 29% of the buyers who dealt in all three species group. In the following section we will assess how sales and purchases are concentrated by small groups of sellers and buyers at the first level of wholesale transactions.

Between the economists' theoretical models of pure competition (many firms acting independently of each other) and pure monopoly (a single firm exploiting its market power) exists a wide range of oligopoly and oligopsony models. I promise not to use these words again. The latter two models refer to a relatively small number of sellers or buyers who act in concert, tacitly or explicitly, to maximize their joint profits. The many economic theories which explain the behavior of a small group of firms differ greatly, but the models have in common the assumption that a small group of sellers or buyers control a large portion of sales or purchases. When sales or purchases are concentrated in such a manner, the group of firms can influence the price of the product. There are many ways of measuring market power (Scherer, 1970). Here we use the most commonly used measure, the percentage of total industry sales (or purchases) for the largest four and eight sellers (or buyers). This measure is usually called the concentration ratio. When the concentration ratio is relatively small, it is unlikely a group of sellers or buyers can influence prices. Either a small group of the largest firms control an insufficient quantity to influence prices, or a larger group that does control a large quantity cannot agree because of the many members. On the other hand, when the

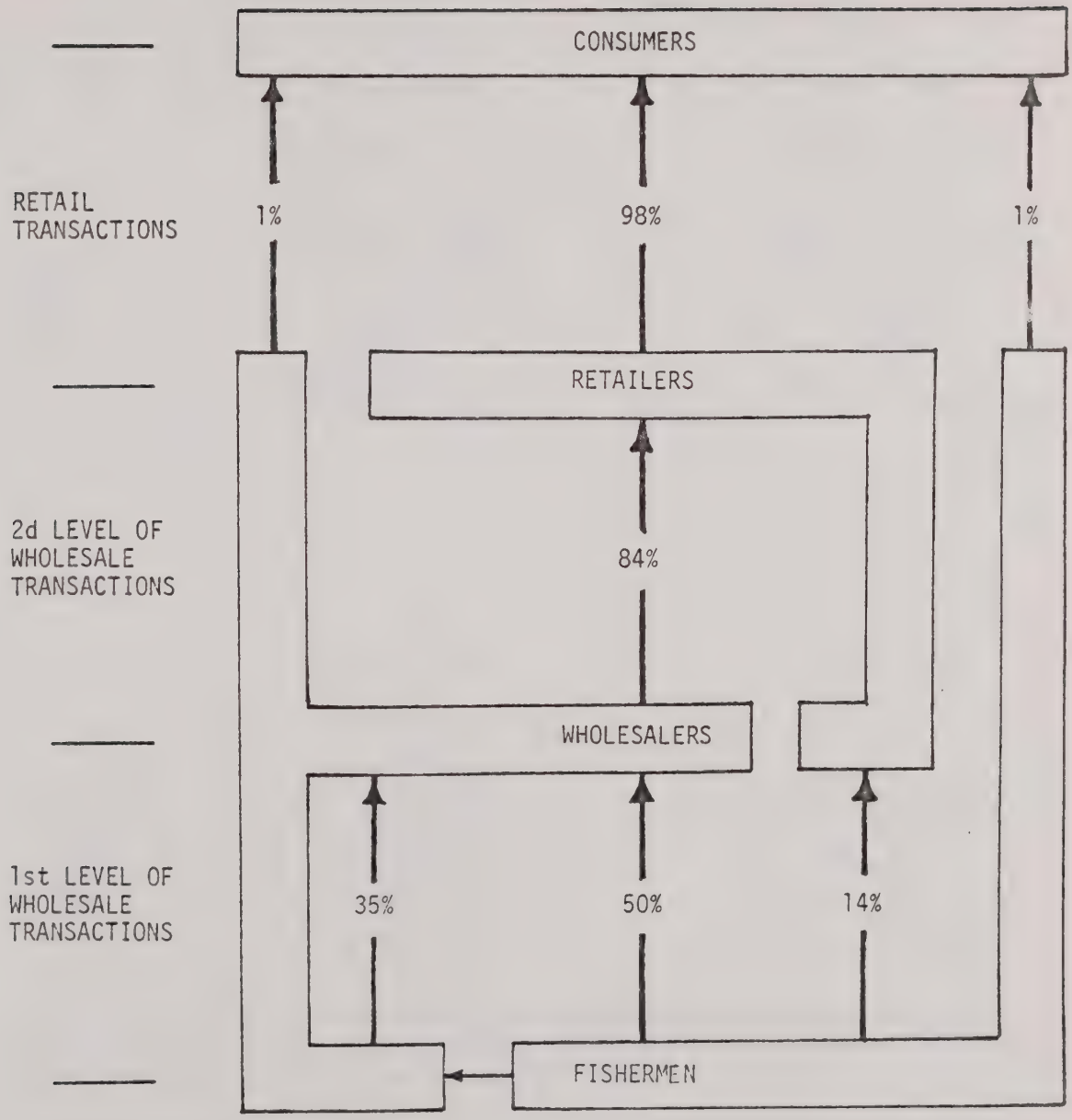

Figure 1.--Distribution of sales at two levels of wholesale transactions and one level of retail transactions in the Oahu Island fresh fish market for all species, 1975-80.

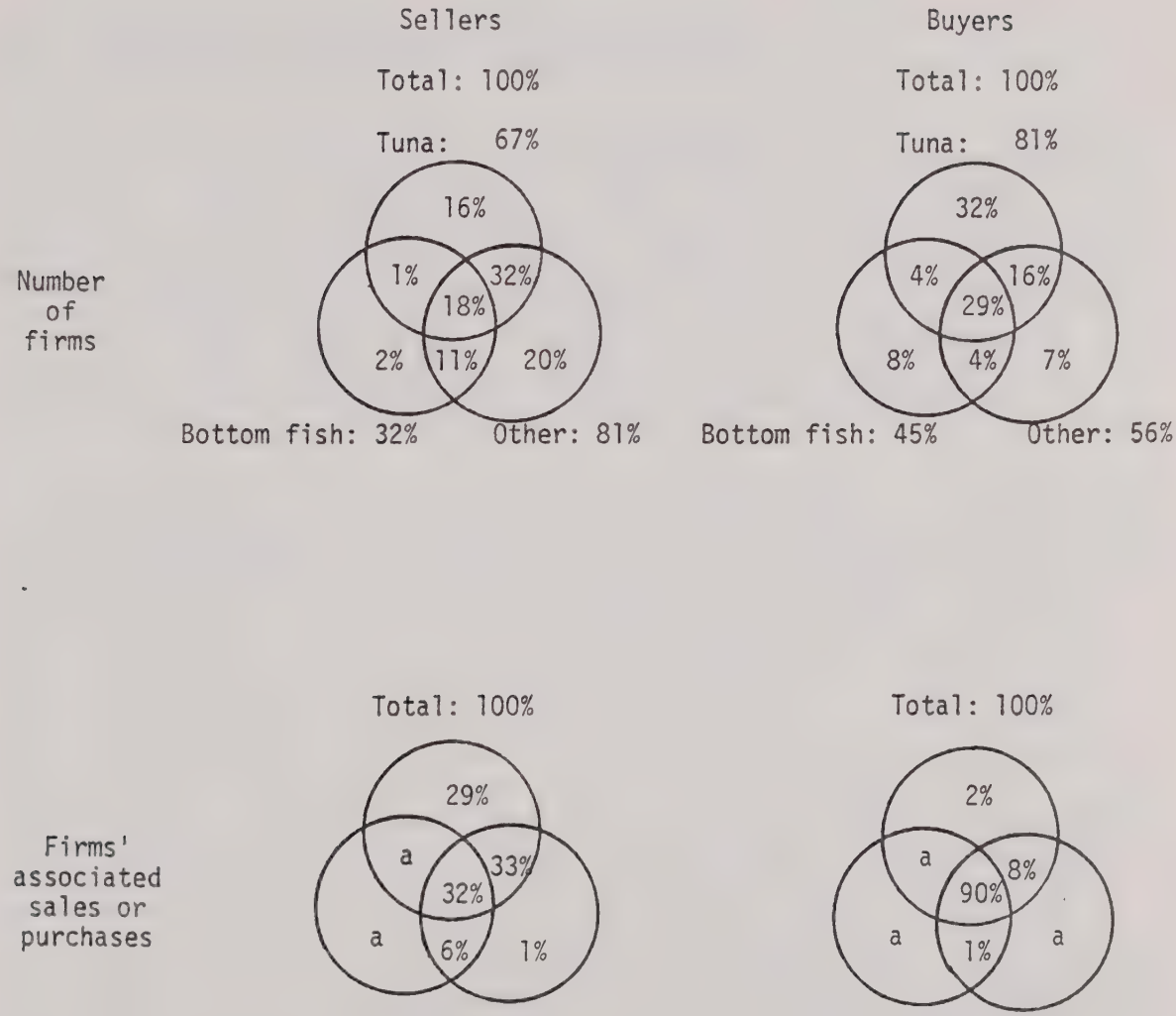

Figure 2.--Distribution of firms and associated sales and purchases, respectively, for sellers and buyers by selected species groups in the Oahu Island wholesale fresh fish market during 1976.

[a]Less than 0.5%.

concentration ratio is relatively high, it is possible the largest firms are able to cooperate, adjusting quantity to stabilize prices over time; at a higher price level by sellers or at a lower price level by buyers.

Thus, when the concentration ratio is high, profit rates may rise above the competitive level at the cost of an exploited group with a resulting net loss to society. There is some dispute over the relationship between profit rates and the degree of seller concentration. Three early studies conclude that a concentration ratio above 70% for the four-largest firms will result in higher profit rates (Bain, 1951; Stigler, 1964; Mann, 1966). A recent study concludes that the concentration ratio for the four-largest firms need only be 55%, and 70% for the eight-largest firms, to find higher profit rates (Meehan and Duchesneau, 1973). The controversy continues in economics and has been expanded by some to conclude that there exists no relationship between the concentration ratio and profit rates (Brozen, 1970).

Applying the first criteria of 70% for the four-largest firms to Table 2 we see the concentration ratios for buyers in 1977 fall below the critical level for each species group. On the sellers side only the concentration ratio for aku sellers exceeds the 70% criteria during 1977. It has been demonstrated how aku sellers may use this apparent market power (Hudgins, 1980). However, actual market power may not exist if close substitute products are available. When aku is aggregated with other tuna species the seller concentration ratio falls markedly--from 99% to 56%. As discussed earlier, it is appropriate to aggregate in this manner when defining the relevant product line if in the fresh fish market other tuna species serve as ready substitutes. Following a second criteria of 55% for the four-largest firms and 70% for the eight-largest, from Tables 2 and 3, 4 of the 10 cases for sellers exceed the critical value. On the buyers side only the four-largest firms for all tunas and all species fall below the critical concentration ratio as well as all species for the eight-largest buyers. Over the 8-year period there is no obvious trend in concentration ratios. With the exception of aku sellers, then, the concentration ratios are not exessively high. However, concentration is not sufficiently low to conclude that sellers and buyers are not able to exercise market power and create market distortions. Therefore information on the underlying behavior of the firms is necessary to further assess market structure.

Concentration ratios above the critical levels will not imply higher profit rates if existing firms know that new firms can easily enter the market. Thus, we now continue with the assessment of structure by analyzing the entry and exit activities for all sellers and buyers of three species groups: all tunas, bottom fish, and all species. These activities are described in Tables 4-9. The tables show the total number of new firms that enter each year, the number of firms leaving the market for a particular species group, the number of firms which enter and exit during the same year, and the resulting total number of firms which participate in the market during the year. For example, from Table 4, during 1970 there were a total of 124 firms selling tuna. By the end of the year, 52 of the firms stopped dealing in tuna or went out of business. In 1971, 54 new firms entered for a new firm total of 126. Of the 54 new firms, 40 left the market by the end of 1971. Another 17 exited the

Table 2.--Annual concentration of sales and purchases, respectively, for the four-largest sellers and buyers of selected species and species groups in the Oahu Island wholesale fresh fish market, 1970-77.

(Percent)

	Four-largest sellers					Four-largest buyers				
Year	Ahi	Aku	All tunas	Bottom fish	All species	Ahi	Aku	All tunas	Bottom fish	All species
1970	34	99	57	66	41	78	62	52	52	48
1971	41	99	63	66	47	78	60	51	52	46
1972	59	99	65	65	48	76	59	51	61	46
1973	31	99	65	59	48	76	56	51	52	45
1974	48	99	68	49	54	64	57	48	57	46
1975	50	99	66	48	49	81	57	51	50	48
1976	39	99	60	45	47	63	59	49	60	45
1977	40	99	56	47	45	57	56	47	63	44

Table 3.--Annual concentration of sales and purchases, respectively, for the eight-largest sellers and buyers of selected species and species groups in the Oahu Island wholesale fresh fish market, 1970-77.

(Percent)

	Eight-largest sellers					Eight-largest buyers				
Year	Ahi	Aku	All tunas	Bottom fish	All species	Ahi	Aku	All tunas	Bottom fish	All species
1970	58	99	71	81	54	95	81	76	78	70
1971	61	99	77	83	58	97	81	75	77	68
1972	65	99	79	86	59	97	80	74	83	65
1973	57	99	76	76	57	93	80	73	74	65
1974	69	99	81	65	66	86	83	73	78	70
1975	71	99	81	67	62	88	84	76	75	70
1976	58	99	74	69	59	82	85	73	82	66
1977	58	99	72	68	58	77	81	71	83	67

Table 4.--Annual entry and exit activity by sellers in the Oahu Island wholesale fresh fish market for all tunas, 1970-77.

Year	(a) Enter	(b) Exit	(c) Same year enter-exit	(d) Active firms	(a+b-c)/d Turnover rate
		(Number of firms)			(%)
1970	--	52	--	124	--
1971	54	57	40	126	56
1972	51	50	37	120	53
1973	58	58	42	128	58
1974	56	56	38	126	59
1975	60	44	30	130	57
1976	124	93	70	210	70
1977	165	--	--	282	--

Table 5.--Annual entry and exit activity by buyers in the Oahu Island wholesale fresh fish market for all tunas, 1970-77.

Year	(a) Enter	(b) Exit	(c) Same year enter-exit	(d) Active firms	(a+b-c)/d Turnover rate
		(Number of firms)			(%)
1970	--	37	--	85	--
1971	14	13	3	62	39
1972	23	24	15	72	44
1973	39	29	23	87	52
1974	25	21	14	83	39
1975	30	31	22	92	42
1976	38	40	29	99	49
1977	34	--	--	93	--

Table 6.--Annual entry and exit activity by sellers in the Oahu Island wholesale fresh fish market for bottom fish, 1970-77.

Year	(a) Enter	(b) Exit	(c) Same year enter-exit	(d) Active firms	(a+b-c)/d Turnover rate
		(Number of firms)			(%)
1970	--	27	--	58	--
1971	29	28	19	60	63
1972	25	23	13	57	61
1973	46	40	30	80	70
1974	38	35	25	78	62
1975	50	43	29	93	69
1976	49	45	33	99	62
1977	95	--	--	149	--

Table 7.--Annual entry and exit activity by buyers in the Oahu Island wholesale fresh fish market for bottom fish, 1970-77.

Year	(a) Enter	(b) Exit	(c) Same year enter-exit	(d) Active firms	(a+b-c)/d Turnover rate
		(Number of firms)			(%)
1970	--	23	--	56	--
1971	14	16	11	47	40
1972	7	8	4	38	29
1973	19	14	11	49	45
1974	16	14	10	51	39
1975	13	11	6	50	36
1976	17	20	14	56	41
1977	14	--	--	50	--

Table 8.--Annual entry and exit activity by sellers in the Oahu Island wholesale fresh fish market for all species, 1970-77.

Year	(a) Enter	(b) Exit	(c) Same year enter-exit	(d) Active firms	(a+b-c)/d Turnover rate
	(Number of firms)				(%)
1970	--	135	--	270	--
1971	77	99	57	212	56
1972	95	81	58	208	57
1973	100	96	66	227	57
1974	85	84	54	216	53
1975	120	102	71	252	60
1976	165	125	94	315	62
1977	245	--	--	435	--

Table 9.--Annual entry and exit activity by buyers in the Oahu Island wholesale fresh fish market for all species, 1970-77.

Year	(a) Enter	(b) Exit	(c) Same year enter-exit	(d) Active firms	(a+b-c)/d Turnover rate
	(Number of firms)				(%)
1970	--	54	--	144	--
1971	28	32	17	118	36
1972	25	40	20	111	41
1973	42	38	28	113	46
1974	36	35	23	111	43
1975	44	45	32	120	48
1976	48	47	35	123	49
1977	38	--	--	114	--

same year. This activity can be described by what I call a turnover rate--the number of new entering firms and exiting firms relative to the total firms in the market. Compensation is made for the double counting of firms which may enter and exit during the same year. We see that under the static concentration ratios is a bustle of activity. In 1976, the turnover rate for tuna sellers was a remarkable 70%. Even if we ignore the firms which enter and exit during the same year, the turnover rate is 55%--39% are new firms (not present in the previous year) and 16%, established firms in the market, exited (making no sales the following year). Tables 8 and 9 cover sellers and buyers of all species. These turnover rates are not markedly lower than for all tunas and bottom fish, which would have suggested that some of the activity could be explained by firms moving about between fisheries. The turnover rate for sellers is always higher than that for buyers. In Table 9 the turnover rate for buyers operating in the wholesale fresh fish market for all species ranged from 36% to 49%. Ignoring the firms which enter and exit the same year, the turnover rate is still greater than 25% for each of the 6 years. All of this entry and exit activity suggests that there are no serious impediments which may prevent the free flow of resources in and out of the markets. When firms see greater opportunities for profits in a fresh fish market, they act without restraint. Larger firms are not protected by what is sometimes referred to as barriers to entry. If larger buyers attempt to restrict their purchases, reducing the price of fish, new buyers move in to bid up the price toward the competitive level. If large sellers cooperated to restrict production, causing prices to increase, new sellers enter with an increase in supply, moving prices back down toward the competitive level. As we will see in the following section, most of the larger sellers and buyers are unsuccessful in maintaining their market position in the face of this bustling market activity.

If we are to further understand the significance of the concentration ratios presented in Tables 2 and 3 we need to understand how the largest sellers and buyers compete for their market positions. Relatively high concentration ratios give firms the opportunity to collude and exercise their market power. But if they are constantly threatened by smaller firms moving up into the ranks of the larger sellers and buyers, it is not likely the larger firms will provide incentives of higher prices to sellers or lower prices to buyers. In addition larger firms which do not maintain their efficiency will be forced down the ranks by more productive expanding firms. Figures 3-11 illustrate the ranking and time track of the eight-largest sellers and buyers for the five selected species groups. The largest firms for each species group are labeled A through H according to their ranking from largest sales or purchases in value. When firms exit the market or otherwise move below the eight-largest firms, their time track terminates or falls below the eighth largest firm. For example, firms E and G in Figure 3 do not get underway since they exit the first year. By 1977 only one of the original firms, B, maintained its market position, but only after pressure by new firms entering the eight-largest sellers of ahi. As discussed earlier, there is not as much entry-exit activity among buyers, but it is important to recognize how much market positions shift over time. Shifting market positions are not captured by the turnover rate, but play an equally important role in explaining the significance of concentration ratios. In four of the five markets a large seller ranks at the top each year, although it is not the same firm in each

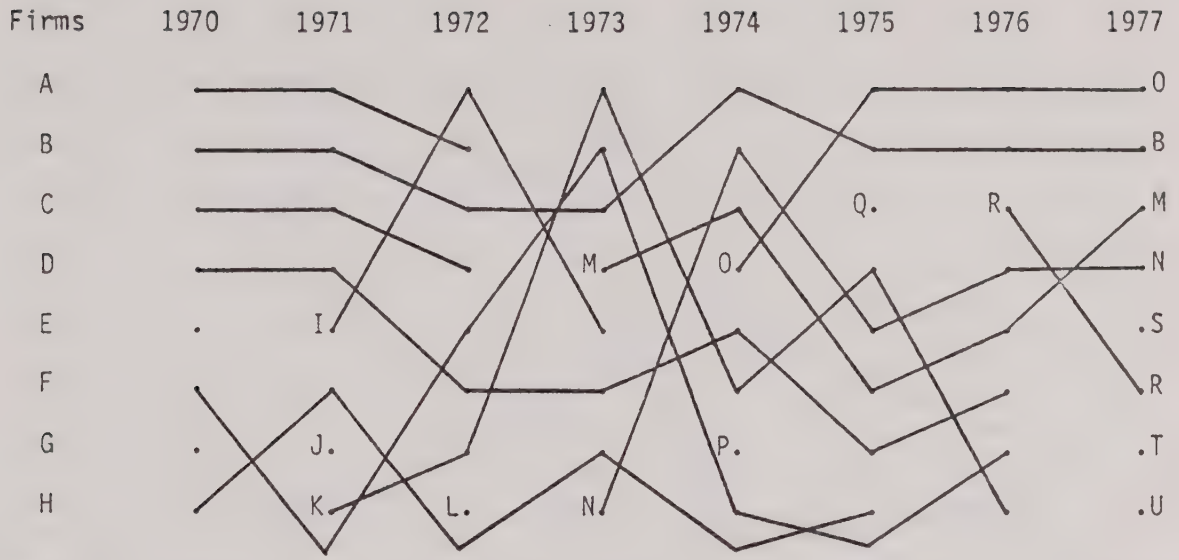

Figure 3.--Annual ranking and time track of the eight-largest sellers of ahi in the Oahu Island wholesale fresh fish market, 1970-77.

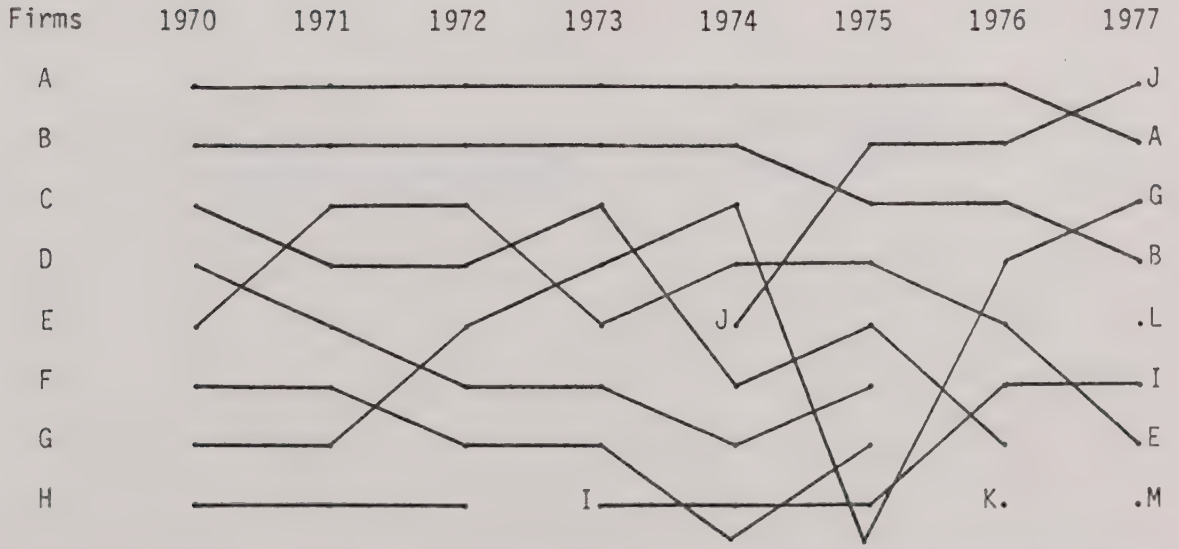

Figure 4.--Annual ranking and time track of the eight-largest buyers of ahi in the Oahu Island wholesale fresh fish market, 1970-77.

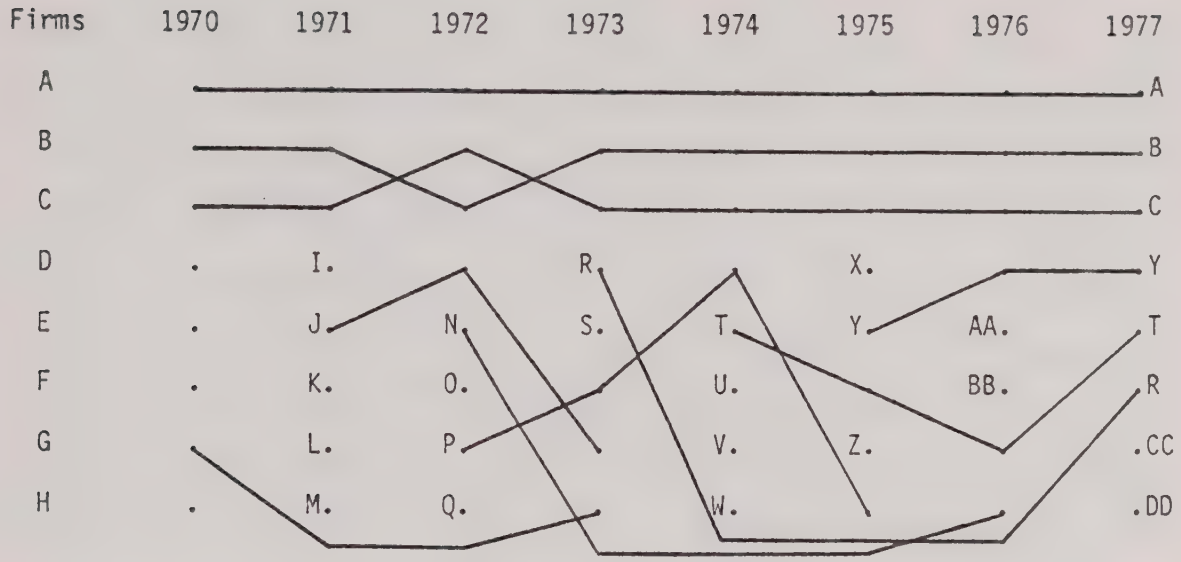

Figure 5.--Annual ranking and time track of the eight-largest sellers of aku in the Oahu Island wholesale fresh fish market, 1970-77.

(Insufficient disaggregated data exists by buyers to complete ranking and time track for aku buyers over the 8-year time period.)

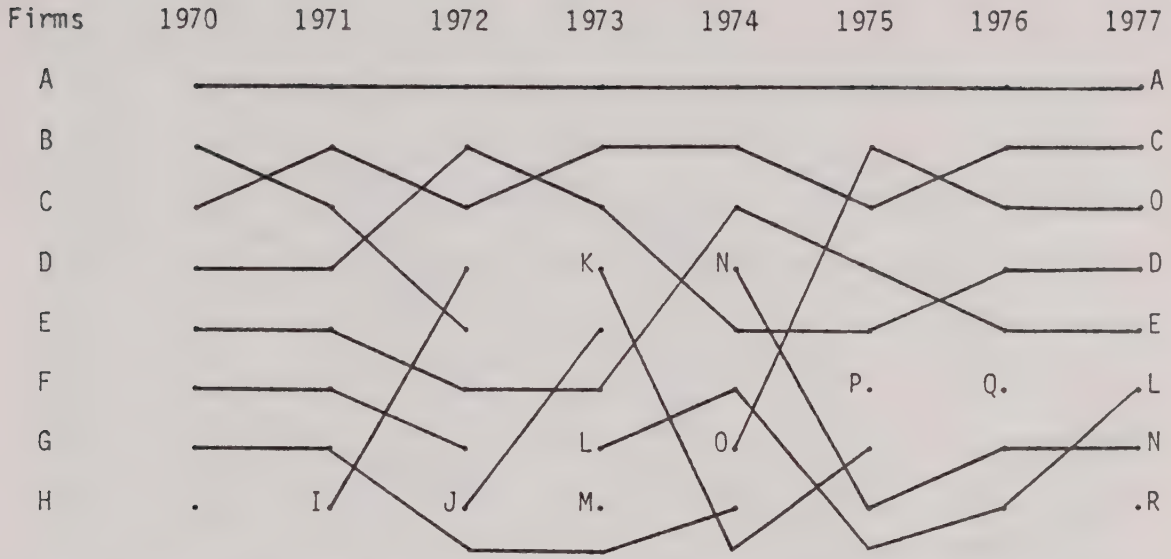

Figure 6.--Annual ranking and time track of the eight-largest sellers of all tunas in the Oahu Island wholesale fresh fish market, 1970-77.

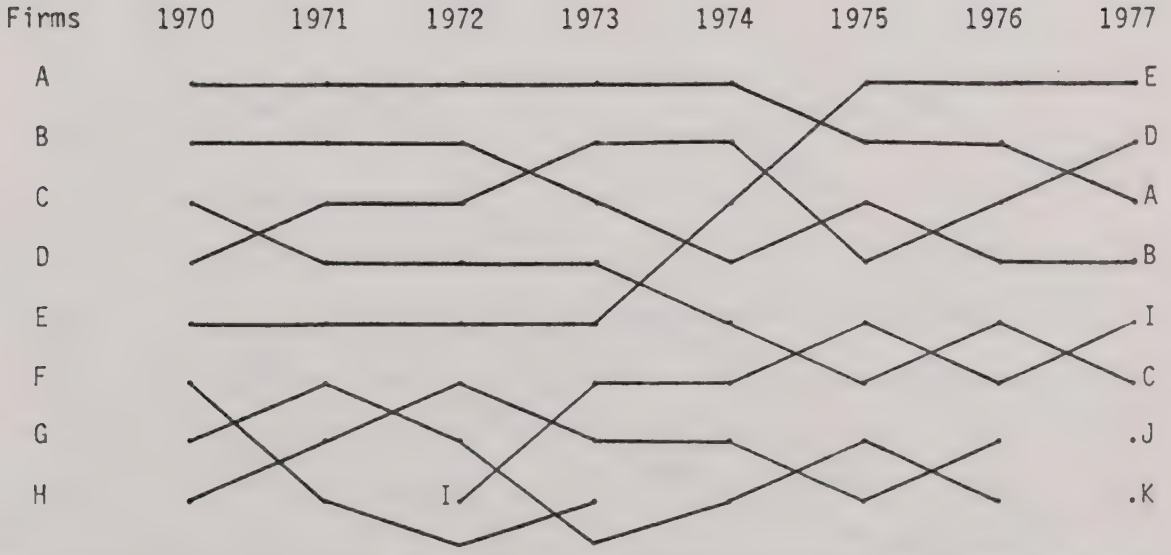

Figure 7.--Annual ranking and time track of the eight-largest buyers of all tunas in the Oahu Island wholesale fresh fish market, 1970-77.

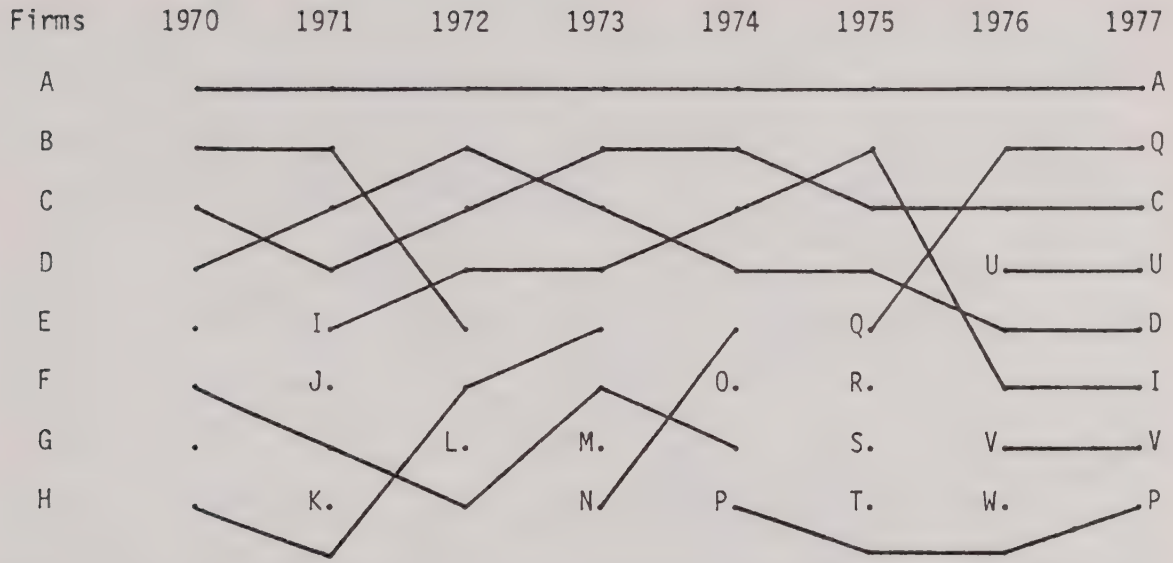

Figure 8.--Annual ranking and time track of the eight-largest sellers of bottom fish in the Oahu Island wholesale fresh fish market, 1970-77.

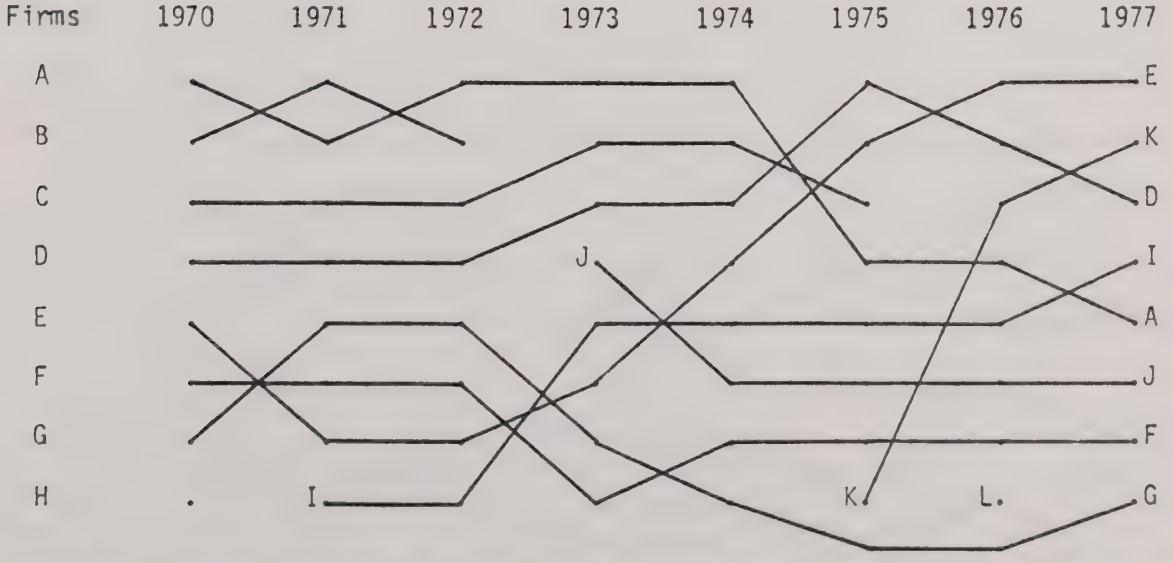

Figure 9.--Annual ranking and time track of the eight-largest buyers of bottom fish in the Oahu Island wholesale fresh fish market, 1970-77.

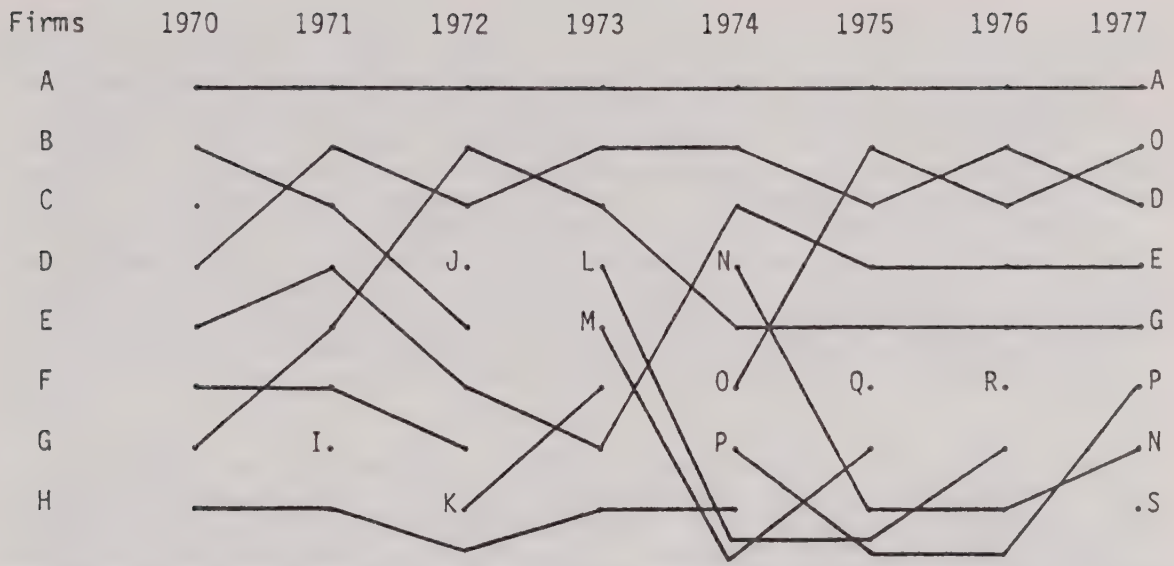

Figure 10.--Annual ranking and time track of the eight-largest sellers of all species in the Oahu Island wholesale fresh fish market, 1970-77.

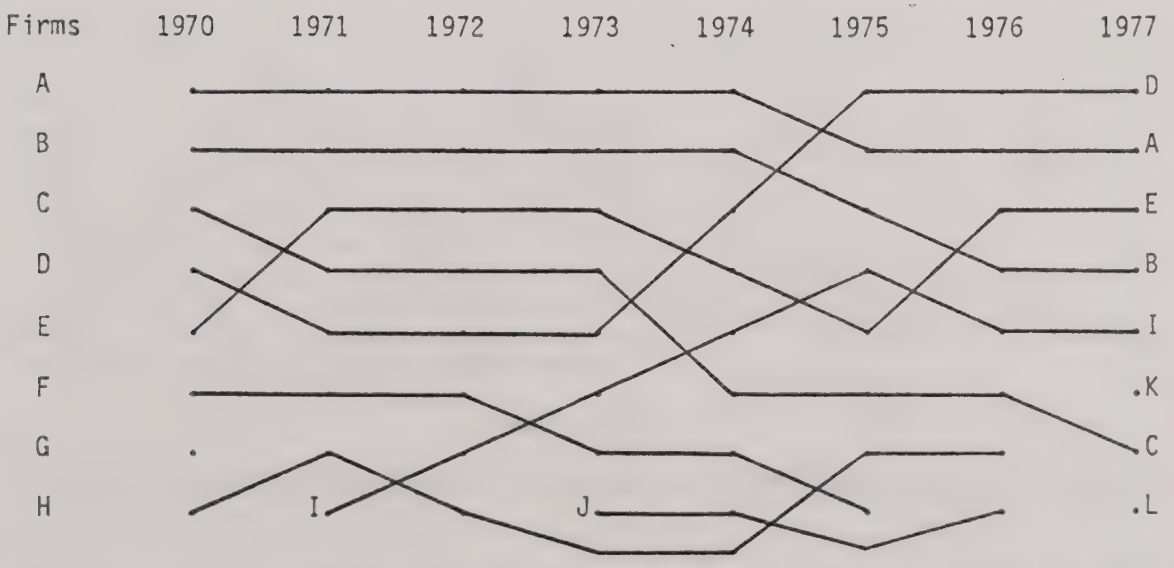

Figure 11.--Annual ranking and time track of the eight-largest buyers of all species in the Oahu Island wholesale fresh fish market, 1970-77.

market. In the aku fishery, Figure 5, the top three firms are not forced out by other firms. For the most part, though, sellers' market positions are extremely volatile. In Figure 10 for all species, only four of the original eight survived the 8 years. Some of the changes in rank or exits from the market are attributed to natural attrition--a vessel sinks or a seller retires. Some of the buyers show interesting trends. In Figure 9 for bottom fish, firm E gets a slow start but demonstrates that it possessed some clear advantage over other firms. The growth of the firm seems to push the four-largest buyers either out of the top eight or reduce their shares. Although there is clearly less entry-exit activity among the buyers compared to the sellers, the shifting of market positions among buyers is extreme. An exception is buyer A of ahi, Figure 4, but firm J enters in 1974 and eventually gains the top position by 1977.

When we tried to identify a trend in concentration ratios over time earlier it was not apparent that the largest concentration of sales and purchases fell into the hands of different firms each year. This is hardly conducive to the exercise of market power. Therefore, it is becoming a more frequent practice in industrial organization studies to assess how the concentration ratio for a given set of firms changes over time. In Tables 10 and 11 concentration ratios are given for the four- and eight-largest sellers and buyers of 1970 over the 8-year period under study. The measures for 1970 are identical to those in Tables 2 and 3. But as time passes the market shares of the largest firms in 1970 are eroded as other firms expand. Aku sellers maintain their market share but as discussed earlier, aku may not be the relevant product line in defining the market if other tunas are good substitutes.

The market structure conditions do not exist in the Hawaii fish industry which would permit sellers or buyers to exercise market power and create market distortions. This conclusion is based on the presence of a large number of sellers and buyers who operate in the industry, the share of the market for the largest sellers and buyers, entry conditions, and how the largest firms maintain their market shares over time. Concentration ratios for sellers and buyers in most of the species groups are not excessively high compared to other industries. However, the market shares of the largest firms are not sufficiently low to conclude that sellers and buyers are not able to exercise market power. Annual entry and exit activity is very high, though, even when discounting for firms which entered and exited the market the same year. Finally, firms do not maintain their market shares in the markets for different aggregated species over the 8-year period.

ACKNOWLEDGMENT

The computer programming for this paper was performed by James C. Cooper.

Table 10.--Annual concentration of sales and purchases, respectively, for the four-largest sellers and buyers in 1970 of selected species and species groups in the Oahu Island wholesale fresh fish market, 1970-77.

(Percent)

Year	Four-largest sellers in 1970					Four-largest buyers in 1970				
	Ahi	Aku	All tunas	Bottom fish	All species	Ahi	Aku	All tunas	Bottom fish	All species
1970	34	99	57	66	41	78	62	52	52	48
1971	40	99	63	66	45	74	60	51	53	45
1972	35	99	65	65	45	72	59	51	62	44
1973	21	99	64	52	42	75	56	51	46	43
1974	27	99	59	39	43	61	56	46	46	44
1975	21	99	54	38	37	51	53	42	40	45
1976	17	99	54	33	36	43	57	40	30	42
1977	14	99	49	32	32	27	51	36	24	40

Table 11.--Annual concentration of sales and purchases, respectively, for the eight-largest sellers and buyers in 1970 of selected species and species groups in the Oahu Island wholesale fresh fish market, 1970-77.

(Percent)

Year	Eight-largest sellers in 1970					Eight-largest buyers in 1970				
	Ahi	Aku	All tunas	Bottom fish	All species	Ahi	Aku	All tunas	Bottom fish	All species
1970	58	99	71	81	54	95	81	76	78	70
1971	59	99	76	75	58	97	81	75	75	67
1972	56	99	76	71	58	97	80	73	80	66
1973	46	99	71	61	51	92	80	71	64	62
1974	43	99	71	45	56	79	83	68	66	64
1975	36	99	65	43	52	66	84	70	63	63
1976	29	99	61	35	46	61	85	67	58	59
1977	23	99	56	36	43	41	80	62	59	56

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HAWAIIAN MONK SEALS AND SEA TURTLES--SIGHTINGS AND DIRECT INTERACTIONS WITH FISHING OPERATIONS IN THE NORTHWESTERN HAWAIIAN ISLANDS

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INTRODUCTION

The Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration (NOAA), began a program of exploratory fishing in the Northwestern Hawaiian Islands (NWHI) in the early 1970's to assess the distribution, abundance, and availability of commercially valuable species of fishes and crustaceans. Early cruises of the NOAA ship Townsend Cromwell determined the presence of large quantities of spiny lobster, Panulirus marginatus, on Necker Bank and subsequent cruises showed that spiny lobsters were distributed throughout the range of the NWHI, although quantities varied considerably with respect to bank and sites on a particular bank. By 1976 commercial fishermen began to harvest this previously untouched resource by means of trap fishing.

The traps used in this fishery are of the California lobster pot type or variations of this basic type. Traps are fished overnight on the bottom and are connected in a string on polypropylene rope; the number of traps per string varying greatly among different boats. Lobster fishing is generally conducted at depths ranging from 27 to 64 m (15 to 35 fathoms).

With the advent of the lobster fishery in the NWHI, an increase in the level of activity around islands associated with the banks has resulted. Among the resident and transient inhabitants of these islands and their surrounding waters are four species of interest which are recognized by the U.S. Government as endangered and threatened species. These species are the Hawaiian monk seal, Monachus schauinslandi, leatherback turtle, Dermochelys coriacea, and hawksbill turtle, Eretmochelys imbricata, which are presently listed as endangered and the green turtle, Chelonia mydas, which is listed as threatened.

STATEMENT OF PROBLEM

Concern has been raised regarding the likelihood of interaction between these species and commercial lobster gear and whether this interaction may act to the detriment of the endangered and threatened species. Since most of the islands in the NWHI chain are a national wildlife refuge, landing on these islands is restricted without special permission. Therefore, the focus of the concern is primarily in terms of the possibilities of detrimental interaction owing to the lobster fishing gear and not on man's physical presence alone.

The following report is an attempt to address this concern and will present in tabulated form available data on sightings and incidences of direct interaction of monk seal(s) and sea turtle(s) with respect to both the lobster fishery and other fishing operations.

TREATMENT OF DATA

Data were grouped into three separate tables depending on the source; i.e., commercial vessel observer cruises (Table 1), Townsend Cromwell cruises (Table 2), and Easy Rider charter cruises (Table 3). Commercial vessel observer cruises were given a letter code to insure the confidentiality of the data. Incidences of direct interactions and sightings were footnoted to describe ship operations at time of observation. In this report the term "direct interaction" refers to any form of interference by the animal(s) with ongoing vessel operations, while

the term "sighting" refers to merely the observation of the animal(s) during ship operations.

RESULTS

Pooling the data from all three sources yields 35 sightings and 3 direct interactions. By source, of the 23 commercial vessel observer trips, a total of 4 sightings of monk seals and 1 direct interaction with a sea turtle were reported. On 20 cruises of the Townsend Cromwell, there have been 8 sea turtle and 21 monk seal sightings and 2 direct interactions with monk seals. Of the three Easy Rider cruises, two monk seal sightings and no direct interactions were observed. With respect to lobster fishing operations, four monk seal sightings and one direct interaction with a sea turtle were reported for all sources combined. Incidences of direct interaction totaled three, two involving monk seals during night-light operations from the Townsend Cromwell and one involving a sea turtle (mentioned above) during lobster fishing operations from a commercial vessel. The latter incident was documented in a Honolulu Laboratory internal report (Appendix).

Table 1.--Observations of monk seals and sea turtles on commercial vessel observer cruises.

Commercial observer trip	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
A	Necker Island	17	10	1,600	None	None
B	Maro Reef	54	28	7,563	None	None
B	Laysan Island		4	984	None	None
B	Necker Island		3	844	None	None
C	Necker Island	11	5	750	None	None
D	Necker Island	14	5	377	None	None
D	Nihoa		1	68	None	None
E	Necker Island	22	12	1,329	None	None
F	Maro Reef	15	5	670	None	None
G	Kure Atoll	52	4	3,412	None	1 sea turtle[1]
G	Midway Islands		3	2,436	None	None
G	Pearl and Hermes Reef		2	1,822	None	None
G	Maro Reef		26	19,776	None	None
H	Necker Island	12	5	750	None	None
H	Nihoa		1	75	None	None
I	Necker Island	18	5	464	1 monk seal[2] 1 monk seal[3]	None

Table 1.--Continued.

Commercial observer trip	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
J	?	11	?	?	?	?
K	Necker Island	11	6	582	None	None
L	Maro Reef	46	32	25,500	1 monk seal[2] 1 monk seal[2]	None
M	Necker Island	14	7	1,244	None	None
N	Necker Island	15	8	1,244	None	None
O	Necker Island	18	4	456	None	None
O	Nihoa		4	381	None	None
P	French Frigate Shoals	14	3	300	None	None
P	Necker Island		3	300	None	None
P	Twin Banks		1	100	None	None
P	Nihoa		1	100	None	None
Q	Necker Island	14	6	718	None	None
R	?	22	?	?	?	?
S	Necker Island	13	7	256	None	None
T	Necker Island	15	9	1,497	None	None
T	Nihoa		1	164	None	None

Table 1.--Continued.

Commercial observer trip	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
U	Necker Island	19	3	282	None	None
U	French Frigate Shoals		1	94	None	None
V	Necker Island	10	5	500	None	None
W	Necker Island	?	7	615	None	None

[1]This incident involved the tangling of a large leatherback turtle in the mainline of a lobster set. This incident was documented in a Honolulu Laboratory internal report (Appendix).

[2]Occurred during lobster fishing operations.

[3]Occurred while at anchor.

Table 2.--Observations of monk seals and sea turtles on Townsend Cromwell cruises.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
75-04	Necker Island	34	4	22	None	None
75-04	Gardner Pinnacles		3	31	None	None
75-04	Pearl and Hermes Reef		1	1	None	None
75-04	Kure Atoll		1	6	None	None
75-04	Lisianski Island		1	9	None	None
75-04	Laysan Island		1	9	None	None
75-04	Nihoa		2	19	None	None
76-06	Necker Island	34	6	144	None	None
76-06	Pearl and Hermes Reef		1	24	None	None
76-06	Niihau		1	24	None	None
76-06	Open ocean		--	--	1 sea turtle[1]	None
77-02 (III)	Necker Island	46	1	32	None	None
77-02 (III)	Raita Bank		1	40	None	None
77-02 (III)	Maro Reef		7	408	None	None
77-02 (III)	Laysan Island		5	324	1 monk seal[1] 2 monk seals[2]	None

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
77-02 (III)	Kure Atoll		3	176	None	None
77-02 (III)	Midway Islands		4	252	None	None
77-02 (III)	Pearl and Hermes Reef		3	216	None	None
77-02 (III)	Salmon Bank		1	72	None	None
77-02 (III)	Lisianski Island		2	144	None	None
77-02 (V)	Maro Reef	44	3	38	1 monk seal[3] 1 monk seal[4]	None
77-02 (V)	Laysan Island		2	22	1 monk seal[4]	None
77-02 (V)	Pearl and Hermes Reef		2	11	1 sea turtle[4]	None
77-02 (V)	Lisianski Island		2	12	1 monk seal[1]	None
77-02 (V)	French Frigate Shoals		--	--	1 sea turtle[3] 1 sea turtle[3] 2 monk seals[4]	None
77-03 (I)	Nihoa	53	3	176	None	None

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
77-03 (I)	Necker Island		6	356	None	None
77-03 (I)	Raita Bank		1	60	None	None
77-03 (I)	Laysan Island		2	120	1 monk seal[1] 1 monk seal[5]	None
77-03 (I)	Lisianski Island		2	120	None	None
77-03 (I)	Pearl and Hermes Reef		2	120	None	None
77-03 (I)	Kure Atoll		2	120	None	None
77-03 (I)	Midway Islands		1	60	None	None
77-03 (I)	Maro Reef		1	60	None	None
77-03 (I)	French Frigate Shoals		4	240	None	None
77-03 (I)	Middle Bank		1	56	None	None
77-03 (I)	Penguin Bank		1	56	None	None

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
78-01 (II)	Open ocean	42	--	--	1 sea turtle[1]	None
78-01 (II)	Nihoa		2	100	None	None
78-01 (II)	French Frigate Shoals		1	60	None	None
78-01 (II)	Kure Atoll		1	60	None	None
78-01 (II)	Midway Islands		2	120	None	None
78-01 (II)	Laysan Island		1	40	6 monk seals[1]	None
78-01 (II)	Necker Island		2	120	None	None
78-01 (II)	Island of Hawaii		1	60	None	None
78-01 (II)	Maui		2	120	None	None
78-01 (II)	Penguin Bank		1	60	None	None
78-03	Lisianski Island	48	1	31	None	None

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
78-03	Pioneer Bank		1	32	None	None
78-03	Raita Bank		1	39	None	None
78-03	Gardner Pinnacles		3	111	None	None
78-03	Niihau		1	16	None	None
78-03	French Frigate Shoals		--	--	1 monk seal[4]	None
78-03	Pearl and Hermes Reef		--	--	1 monk seal[1]	None
78-04	Necker Island	20	3	160	None	None
78-04	French Frigate Shoals		2	102	None	None
78-04	Maro Reef		2	112	None	None
78-04	Nihoa		1	56	None	None
79-02 (I)	Midway Islands	30	1	16	None	None
79-02 (II)	Pearl and Hermes Reef	37	1	60	None	None
79-02 (II)	Lisianski Island		2	100	None	None
79-02 (II)	Laysan Island		1	60	None	None
79-02 (II)	Brooks Bank		2	109	None	None

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
79-02 (II)	Necker Island		6	326	None	None
79-02 (II)	Nihoa		--	--	1 monk seal[4]	None
79-03	Necker Island	47	1	34	None	None
79-03	French Frigate Shoals		2	67	None	None
79-03	Maro Reef		2	54	None	None
79-03	Laysan Island		1	34	None	None
79-03	Lisianski Island		1	35	1 sea turtle[1]	None
79-03	Pearl and Hermes Reef		3	108	None	None
79-03	Midway Islands		1	28	None	None
80-02	Necker Island	48	3	151	None	None
80-02	Raita Bank		1	38	None	None
80-02	Pearl and Hermes Reef		2	64	None	None
80-02	Ladd Bank		1	40	None	None
80-02	Salmon Bank		1	40	None	None
80-02	Northampton Bank		1	40	None	None
80-02	French Frigate Shoals		--	--	None	1 monk seal[6]

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
80-03 (I)	Kure Atoll	30	2	8	1 monk seal[1]	None
80-03 (II)	Maro Reef	32	3	12	None	None
80-03 (II)	Lisianski Island		2	8	None	None
80-03 (II)	Pearl and Hermes Reef		2	8	None	None
80-03 (II)	Kure Atoll		2	8	None	None
80-03 (II)	French Frigate Shoals		--	--	2 monk seals[1]	None
80-04 (I)	French Frigate Shoals	23	--	--	1 monk seal[7]	None
80-04 (II)	Necker Island	32	3	120	None	None
80-04 (II)	Brooks Bank		3	120	None	None
80-04 (II)	St. Rogatien Bank		3	120	None	None
80-04 (II)	Raita Bank		4	135	None	None

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
80-04 (II)	Maro Reef		4	122	None	None
80-04 (II)	Gardner Pinnacles		2	48	None	None
80-05 (II)	Necker Island	43	2	73	None	None
80-05 (II)	Laysan Island		1	24	1 monk seal[1]	None
80-05 (II)	Pogy Bank		1	24	None	None
80-05 (II)	Ladd Bank		1	24	None	None
80-05 (II)	Maro Reef		1	24	None	None
80-05 (II)	Gardner Pinnacles		2	48	None	None
80-05 (II)	Midway Island harbor		--	--	6 sea turtles[4]	None
80-05 (II)	French Frigate Shoals		--	--	1 monk seal[4]	2 monk seals[8]
81-01	Nihoa	40	2	59	None	None

Table 2.--Continued.

Townsend Cromwell cruise	Area (bank)	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
81-01	Nihoa	40	2	59	None	None
81-01	Bank #3		1	32	None	None
81-01	Necker Island		2	64	None	None
81-02	Pearl and Hermes Reef	36	2	64	None	None
81-02	Ladd Bank		2	64	None	None
81-02	Maro Reef		2	64	None	None
81-02	French Frigate Shoals		2	64	None	None
81-02	Necker Island		2	64	None	None
81-02	Laysan Island		--	--	1 monk seal[4]	None
81-03	Open ocean	18	--	--	1 sea turtle[1]	None
81-03	French Frigate Shoals		--	--	1 monk seal[4]	None
81-03	Middle Bank		--	--	1 monk seal[9]	None

[1]Occurred while underway.
[2]Occurred during lobster fishing operations.
[3]Occurred during trolling operations.
[4]Occurred while at anchor.
[5]Occurred during period of multiple fishing operations.
[6]A monk seal began to interfere with night-light operations by chasing attracted fish away from the light. Subsequently the seal began tugging on the night-light by grasping the electrical cord near the base of the light with its mouth.

[7]Occurred during environmental station.

[8]Occurred during a night-light operation. A monk seal was first observed around the light at 1900. By 2000 a second seal appeared and began actively feeding around the night light. At 2200 the two seals began interfering with opelu (mackerel scad, Decapterus sp.) fishing under the light by taking the hooked opelu off the lines before they could be retrieved.

[9]Occurred during handlining station.

Table 3.--Observations of monk seals and sea turtles on Easy Rider charter cruises.

Easy Rider charter cruise	Area	Duration of trip (days)	Days lobster fishing	Total traps hauled	Sightings of monk seals and sea turtles	Direct interaction
77-02 (I)	Gardner Pinnacles	20	1	59	None	None
77-02 (I)	St. Rogatien Bank		1	59	1 monk seal[1]	None
77-02 (I)	French Frigate Shoals		2	79	None	None
77-02 (I)	Necker Island		8	598	None	None
77-02 (II)	Nihoa	23	2	196	None	None
77-02 (II)	Necker Island		8	703	None	None
77-02 (II)	Maro Reef		2	200	None	None
80-01	Maro Reef	15	--	--	1 monk seal[2]	None

[1]Occurred while underway.

[2]Occurred during undetermined ship operations.

APPENDIX

REPORT OF THE ACCIDENTAL CAPTURE AND RELEASE OF A LEATHERBACK TURTLE IN THE NORTHWESTERN HAWAIIAN ISALNDS

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On September 22, 1980 while fishing at Kure Atoll aboard the Easy Rider Too, an adult leatherback turtle, Dermochelys coriacea, was brought to the surface while retrieving lobster gear. The turtle's left front flipper had become entangled in the polypropylene rope which connected a string of 253 lobster traps. As the turtle was hauled slowly to the surface, it offered no resistance and though alive, it made very little movement on its own. No attempt was made to lift the turtle out of the water and aboard the ship. Efforts made to untangle the turtle from the ship failed; the turtle began to roll over, entangling its head in the line and thereby submerging its head below the surface. At this point the captain, Gary "Skip" Naftel, decided to enter the water and attempt to free the turtle. Whether the line was untangled or cut is not recalled, but the turtle was subsequently released and appeared to swim slowly down underneath the ship and out of sight. The elapsed time from the turtle's retrieval to its release was approximately 15-30 minutes.

The trap string had been set at 1745 on September 20, 1980 and retrieval started at 0747 on September 22, 1980. The incident occurred in the morning sometime between 0800 and 1000. The depth of the fishing site ranged from 29 to 40 m (16 to 22 fathoms) and the end to end position of the string was as follows:

Lat. 28°21.45'N, long. 178°19.5'W to lat. 28°23.6'N, long. 178°24.9'W

Unfortunately, no record was made as to which end of the lobster string the incident took place.

Three photographs of the incident were taken and are included in the report. While in the water alongside the turtle the captain of the Easy Rider Too estimated the carapace length at 5 feet. The apparent condition of the turtle upon release was uncertain since it moved slowly away and was observable only for a very short time. The only apparent physical damage to the turtle was in imprint of the polypropylene line at the base of the left front flipper.

1

2

3

Photographs 1 and 2 show the entangled leatherback turtle off the starboard side of the ship. In photograph 3, the turtle has rolled over in the water while the captain attempts to remove the line from around the turtle's head and flipper.

THE PRESENT STATUS OF THE SPINY LOBSTER FISHERY IN HAWAIIAN WATERS

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Introduction

The spiny lobster, Panulirus marginatus and P. penicillatus, fishery in the Hawaiian Archipelago consists of a primarily recreational or subsistence fishery in the main Hawaiian Islands and a newly developed commercial fishery for P. marginatus in the Northwestern Hawaiian Islands (NWHI). These fisheries have recently been described in the "Source Document for the Final Fishery Management Plan of the Spiny Lobster Fisheries of the Western Pacific Region," dated May 1981, issued by the Western Pacific Regional Fishery Management Council.

The purpose of this report is to describe the fishery as it exists today. Most of the information was gathered through informal interviews with participants in the fishery. Some data collected by other agencies or for other purposes have been summarized for presentation here.

Estimation of Spiny Lobster Catch

Records of the reported catch of spiny lobster in the Hawaiian Archipelago are available back to at least 1948 in the data files of the Hawaii Division of Aquatic Resources (HDAR; formerly the Hawaii Division of Fish and Game). These records are based on fish catch reports that are submitted to HDAR for catches subsequently sold in the state. There is believed to be a substantial catch by purely recreational fishers in the main Hawaiian Islands on which no data are collected. As can be seen from Table 1, the spiny lobster catches decreased steadily from approximately 19,051 kg (42,000 lb) in 1948 to 1,959 kg (4,319 lb) in 1975. The reported catch has gone up since 1976 due to the initiation of the P. marginatus fishery in the NWHI.

Since the fishery in the NWHI is presumably conducted entirely in the U.S. Fishery Conservation Zone (FCZ), which lies outside the jurisdiction of the state, most of the boats participating in the fishery do not now report their catches to HDAR. Thus, the more recent records from HDAR do not represent the total commercial catch in the Hawaiian Archipelago. Also, since there presently is no fishery management plan (FMP) as yet to regulate the fishery in the FCZ, the industry is under no legal requirement to report their catches. Thus, there is no official public record of the complete catches in the NWHI.

Table 1.--Catch of spiny lobsters reported to the Hawaii Division of Aquatic Resources, for the main Hawaiian Islands and the Northwestern Hawaiian Islands.

	Main Hawaiian Islands		Northwestern Hawaiian Islands		Total Hawaiian Archipelago	
Year	kg	lb	kg	lb	kg	lb
1948					19,219	42,370
1949					19,791	43,632
1950					15,428	34,012
1951					7,856	17,230
1952					8,188	18,052
1953					8,136	17,938
1954					6,804	14,999
1955					7,316	16,136
1956					5,775	12,732
1957					6,528	14,392
1958					4,169	9,192
1959					5,597	12,339
1960					4,750	10,473
1961					5,734	12,642
1962					3,578	7,890
1963					4,662	10,277
1964					4,467	9,846
1965					3,700	8,158
1966					2,486	5,481
1967					2,002	4,415
1968					2,155	4,751
1969					4,195	9,250
1970					2,448	5,398
1971					2,785	6,140
1972					2,426	5,349
1973					2,529	5,577
1974					2,026	4,467
1975	1,959	4,319	--	--	1,959	4,319
1976	6,865	6,317	--	--	2,783	6,317
1977	6,112	13,474	31,547	69,549	37,659	[1]83,023
1978	2,854	6,292	12,440	27,427	15,294	33,719
1979					9,544	21,041

[1]The Fishery Management Plan dated May 1981 indicates a total catch of 85,839 lb in Table 7.7.

Because of this lack of information on the activities in the NWHI, the Honolulu Laboratory has initiated a project to obtain the information by conducting informal interviews with persons associated with the spiny lobster industry. This project is being conducted by the junior author, Bernard M. Ito, and Gary L. Steiger. All of the information presented in this report was gathered through their efforts.

Based on this informal means of collecting data, we estimate that the 1980 spiny lobster catch in the NWHI was approximately 148,780 kg (328,000 lb) made by three boats on 12 trips (Table 2). Through August 1981, we estimate the catch to be nearly 295,747 kg (652,000 lb) made by 7 boats on 16 trips. We have no data on two additional boats in the fishery, except that one of them made two trips.

Table 2.--Estimates of catch and number of trips for the spiny lobster fishery conducted in the Northwestern Hawaiian Islands obtained via informal interviews. Estimated whole weight of frozen tails is based on tail weights averaging 35.6% of total weight as calculated from Uchida et al. 1980.

		Whole live		Frozen tails				Total whole	
				Tail only		Estimated whole			
Year	Trips	kg	lb	kg	lb	kg	lb	kg	lb
1980	12	5,171	11,400	51,170	112,809	143,736	316,879	148,907	328,279
1981[1]	16	11,635	25,651	101,132	222,956	284,081	626,281	295,716	651,932

[1]Incomplete.

The draft FMP estimates a maximum sustainable yield (MSY) of 200,000-378,000 lobsters in the NWHI. If we take an estimate of the average weight of lobsters at the point of MSY to be 515.5 g, 85 mm carapace length (1.15 lb), then in terms of weight the MSY would be 104,328-197,179 kg (230,000-434,700 lb). Thus, the estimated catch in 1980 falls within the MSY range, whereas in 1981 the estimated catch already exceeds the MSY range.

Number of Boats in Fishery

Since the start of the spiny lobster fishery in the NWHI in 1976, there has been a total of 14 different boats participating in the fishery. Although the figures for 1981 are as yet incomplete, 1981 has been the most active year in the NWHI fishery in terms of the number of boats operating and the number of fishing trips (Table 3).

Fishing Vessels

Although a few of the vessels in the NWHI spiny lobster fishery primarily target lobsters, most of the vessels are multi-purpose fishing boats or can easily be converted for other fisheries. The vessels that have participated

Table 3.--Growth of the Northwestern Hawaiian Islands spiny lobster fishery, 1976 to August 1981.

	Year					
	1976	1977	1978	1979	1980	1981
Number of vessels	2	5	2	2	3	9
Estimated number of trips	3	14	12	6	12	20

in the fishery have ranged from 17.3 to 56.1 m (57 to 185 ft) and have had carrying capacities ranging from 27 metric tons (MT) (30 short tons (ST)) to approximately 227 MT (250 ST). Their trap-carrying capacity have ranged from 300 to 2,000-3,000 traps and the number in the crew have ranged from 2 to 18 fishermen.

The four boats currently participating in the fishery have a combined carrying capacity of about 727 MT (800 ST) and can carry a total of 3,900 traps. Only one of the boats specializes in live lobsters; the others land mostly frozen tails. The latter vessels all have brine, blast, and holding freezers.

Many of the boats have the capability of fishing for bottom fish, and they often do so during lobster fishing trips.

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RECENT TRENDS IN THE JAPANESE FISHERY FOR SQUID, *OMMASTREPHES BARTRAMI*

NOV 3 2 1981
National Marine Fisheries Service
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By

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October 1981

This report was prepared in September 1981 by William G. Court who compiled and translated information from various Japanese fishery press items and information gathered from various Japanese industry and government sources. The report was prepared at the request of the Honolulu Laboratory through the courtesy of Robert T. B. Iversen, Regional Fishery Attache, American Embassy, Tokyo, Japan. Tamio Otsu, Southwest Fisheries Center, Honolulu Laboratory, translated parts of the text accompanying the tables and illustrations that were left untranslated by W. Court.

Japan's larger squid jigging boats have been jigging for aka-ika (red squid), Ommastrephes bartrami, in the North Pacific Ocean since 1975. The drift gill net fishery developed very rapidly in 1978 and soon expanded, at one point, to include 1,000 boats. This fishery has been a source of controversy and problems almost since its inception--the primary problem being competition with the less efficient squid jigging boats. However, by the action of the Central Fisheries Adjustment Committee, which met from late May 1981, the free status of this fishery has ended, i.e., participation in the fishery must be authorized, as of August 1, 1981.

The reasons for this action include the fact that the drift gill net fishery competes severely with the existing squid jigging fishery for the same species. Also, because of the extremely high efficiency of the drift gill net fishing method, the conservation of the resource cannot be left to itself. Furthermore, as salmon is an incidental catch of this fishery there is apprehension that this will lead to international problems.

The new regulations provide that boats may not participate in the fishery without a permit, which is issued to selected boats by the Minister of the Ministry of Agriculture, Forestry and Fisheries. Boats must be between 50 and 500 tons; the regulated fishing area is north of lat. 20°N. However, within this area, fishing is to be allowed only east of long. 170°E. The mesh size of the nets is to be greater than 10 cm. Landings may be made at any 3 of 30 designated landing ports, subject to approval of the ports selected by the particular boat.

This Central Fisheries Adjustment Committee action is the result of a 2-year controversy between the organizations representing the drift gill net fishery and the squid jigging fishery. The Japan Fisheries Agency has mediated the controversy.

The 1981 drift gill net squid season is 5 months long, from August through December, and the 1982 season will run from June for 7 months. Many of the drift gill net permits have been obtained in exchange for squid jigging permits as a means of reducing the number of squid jigging participants. In September 1981 the All Japan Large Vessel Squid Jigging Association announced a one-third reduction in the number of its member boats from 212 to 140 boats. As of mid-September 1981 a total of 534 boats held permits in the new fishery, including 163 boats over 100 tons and 371 under 100 tons.

Landings of red squid were 144,000 metric tons (MT) (200,000 MT round weight equivalent) of which over 95% were frozen. The landings forecast for 1981 are from 125,000 to 144,000 MT (180,000 to 200,000 MT round weight equivalent). The very low price of squid in 1980 forced many drift gill net boats to work overtime to process the squid on board and to freeze only the mantles, as this would bring a higher return in the market place and enable the boats to at least minimize their deficit.

Table 1.--The number of fishing days (N) and catch per day's fishing per vessel (CPUE) of the large aka-ika jigging vessels of Kanagawa Prefecture. (Source of data: Kanagawa Prefectural Fisheries Experimental Station.)

		July	August	September	October	November	Total
N	1979	150	454	419	426	133	1,582
(days)	1980	77	309	300	172	17	875
CPUE	1979	104	227	236	147	76	184
(No. of cases)	1980	292	274	377	358	282	327

Table 2.--The catch per day's fishing per vessel of aka-ika by the large vessels. (Source of data: Tohoku Regional Fisheries Research Laboratory and Kushiro Fishery Experimental Station.)

Unit: Metric ton

Fishing gear	Year	July	August	September	October	November	Total
Jigging	1978	1.630	2.920	2.090	2.160	2.770	2.270
	1979	(0.846)	2.464	2.697	1.830	(0.551)	2.178
	1980	3.548	2.986	3.842	3.394	--	3.438
Gill net	1979	4.225	4.914	5.105	4.899	(4.082)	4.823
	1980	(10.921)	(14.856)	(10.173)	(5.744)	(6.324)	(10.697)

Note: 1) Parentheses indicate catches made during less than 100 fishing days.

2) The 1980 gill net data are based on catches of one vessel only. This vessel used 600-800 shackles of gill net; mesh size 115 mm.

Table 3.--Annual landings of aka-ika.

Unit: Metric ton

	Total landings[1]			Estimated landings by fishing method	
	Fresh	Frozen	Total	Jigging	Drift gill net
1975	20,176	20,988	41,164	41,164	0
1976	31,035	53,145	84,180	84,180	0
1977	29,813	91,955	121,768	121,768	0
1978	52,939	92,369	151,308	100,000-110,000	40,000-50,000
1979	30,785	93,867	124,652	70,000-80,000	40,000-50,000
1980	10,745	133,546	144,291	69,105	75,186
	(10,745)	(177,155)	(187,900)	69,105	118,795

Note: 1) Based on data provided by the National Federation of Fisheries Cooperatives (Zengyoren). The 1980 landings include squid gutted on board (tsubonuki). The figures in parentheses were based on estimates of ungutted squid weights obtained as follows:

a. Since virtually all of the fresh squid were taken by jigging, these were all considered to be ungutted.

b. It was estimated that 43.7% of the frozen squid had been taken by jigging and 56.3% by gill net. All of the jig-caught squid were assumed to be ungutted. Of the gill net-caught squid, 41.2% were estimated to be ungutted and 58.4% were tsubonuki or squid gutted on board.

c. To convert from gutted squid to ungutted weight, the gutted squid weight was multiplied by 2.0.

Table 4.--The number of fishing days (N) and catch per day's fishing per vessel (CPUE) of aka-ika by the jigging vessels of Aomori Prefecture.

		1976	1977	1978	1979	1980
N (days)	Medium-sized freezer vessel	7,722	10,492	16,185	11,568	3,025
	Large-sized vessel	2,756	4,697	7,812	7,125	6,400
	Total	10,478	15,189	23,987	18,693	9,425
CPUE[1] (No. of cases)	Medium-sized freezer vessel	191	216	139	147	191
	Large-sized vessel	230	233	217	174	262

[1] Fishing period = July-December.
Data source: Aomori Prefectural Fisheries Experimental Station.

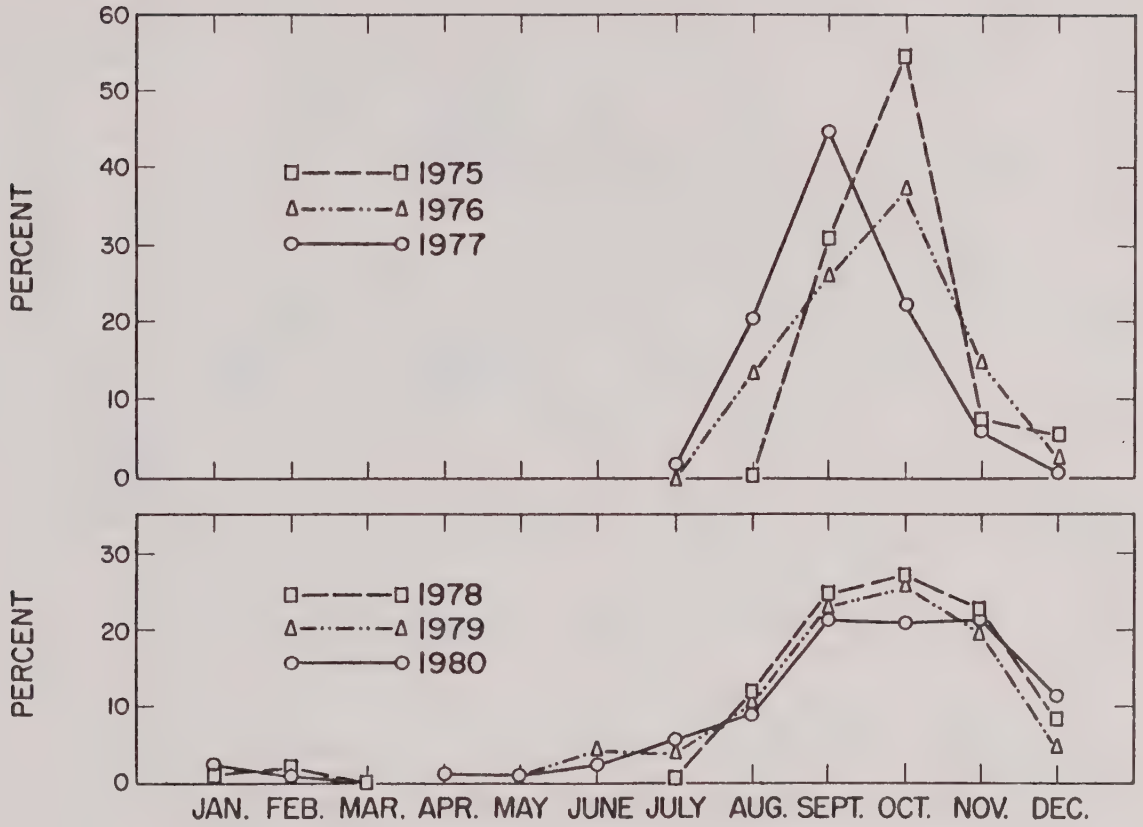

Figure 1.--Comparison of monthly landings of aka-ika. (Top panel = jigging only; lower panel = jigging and drift gill netting.) Data for 1975 provided by Tohoku Regional Fisheries Research Laboratory's Hachinohe Branch Station; 1976-80 data provided by the National Federation of Fisheries Cooperatives (Zengyoren); and the 1980 data include tsubonuki (squid gutted on board).

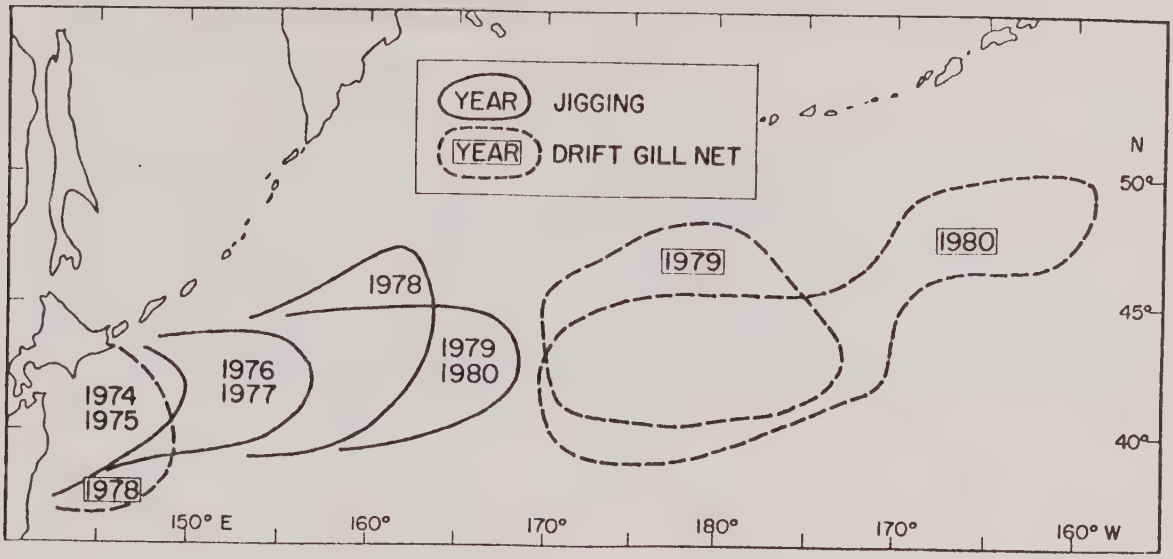

Figure 2.--Annual change in fishing grounds for aka-ika.

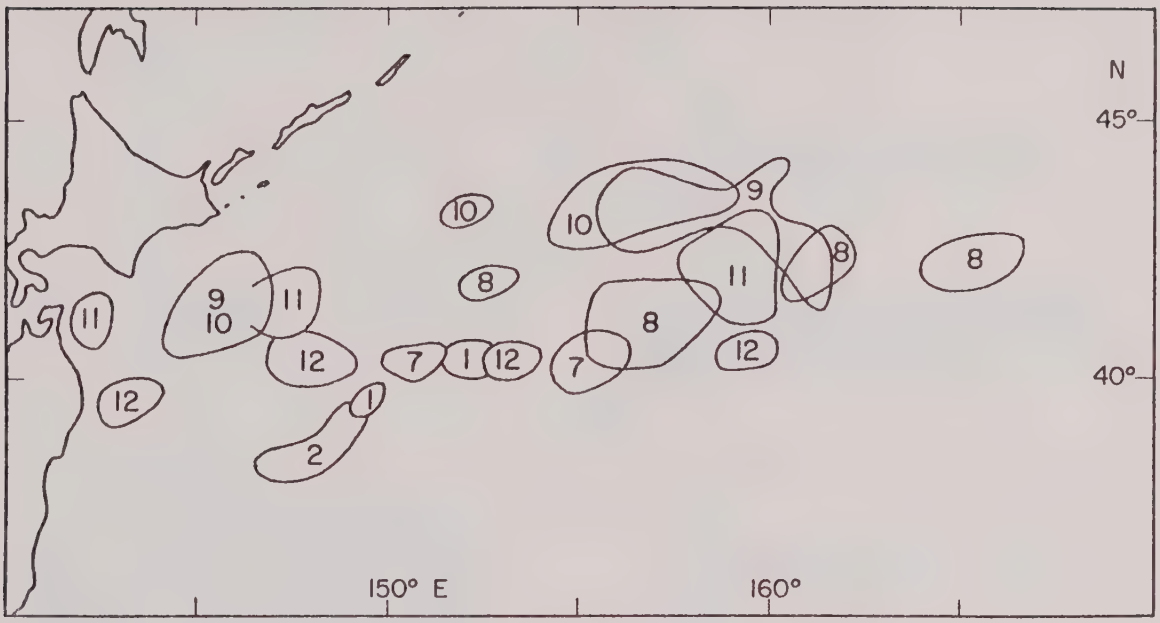

Figure 3.--The main jigging grounds for aka-ika by month, from July 1980 through February 1981. (Source of data: Tohoku Regional Fisheries Research Laboratory, Kushiro Fisheries Experimental Station, Aomori Prefectural Fisheries Experimental Station, and Fishery Situation Report Service Center. Legend: Numbers = months.)

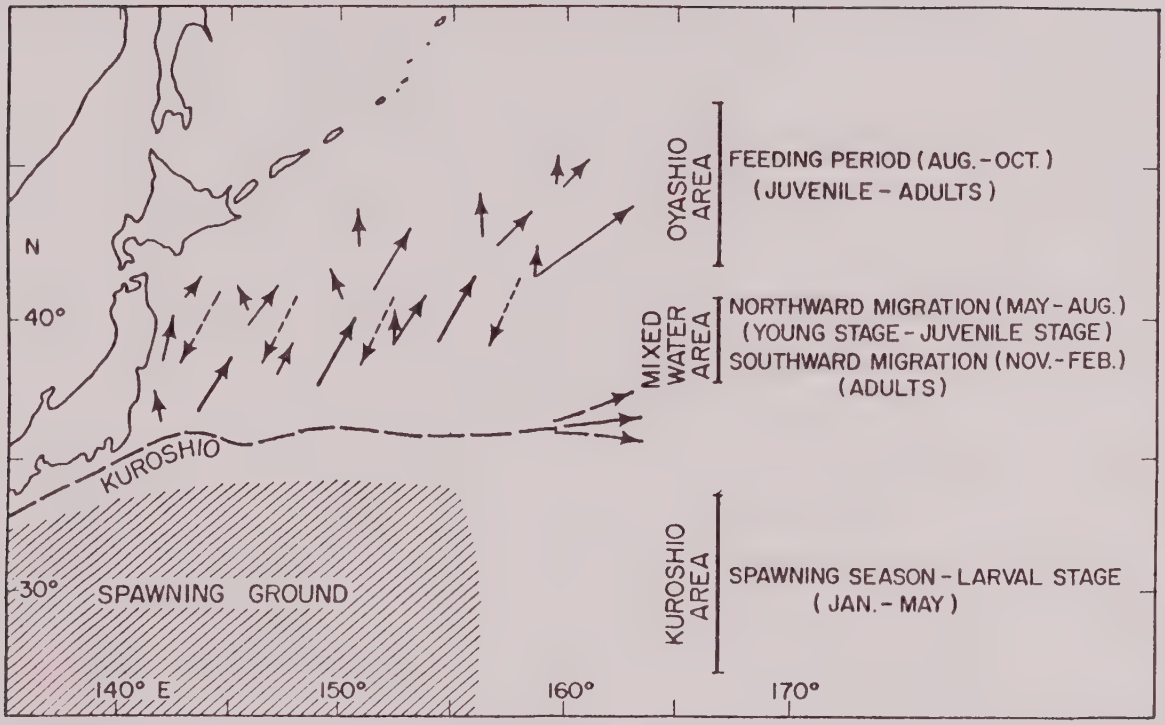

Figure 4.--The migration pattern of aka-ika.

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SEAMOUNT FISHERY
FOREIGN VESSEL OBSERVER REPORT, KITAKAMI MARU
(AUGUST 15 TO OCTOBER 1, 1981)

By

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November 1981

SEAMOUNT FISHERY
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In May of 1981 Nippon Suisan of Tobata, Japan, notified the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, of their intention to send two trawlers to fish in the U.S. Fishery Conservation Zone (FCZ) on the Hancock Seamounts, located northwest of Midway Islands. The Aso Maru entered the FCZ in June; on board the vessel was U.S. Observer Nathaniel Shippen of the Honolulu Laboratory (see SWFC Admin. Rep. H-81-4). Over 400 tons of Japan's 1,000-ton quota of western Pacific seamount groundfish were taken by the Aso Maru in 9 days. The smaller Kitakami Maru, another veteran of the seamount trawl fishery, was then designated to take the balance of the 1981 allocation. It was requested that the observer for the Kitakami Maru board that ship in Japan to eliminate expensive running time to Midway from the fishing grounds. Departure date was set for August 3. The decision to wait until the latter part of the season was presumably based on catch rates in previous years, as well as on the success of the Aso Maru earlier this year. There may have been other factors such as scheduled maintenance and crew rotation after the winter season prawn fishery in the East China Sea. Whatever the reasons for waiting, by August and September the catch rates of armorhead and alfonsin had dropped drastically and resulted in only 244 tons of the remaining quota of 582 tons being caught. This season was perhaps the worst ever for the Japanese in this fishery, both inside and outside of the FCZ.

I boarded the Kitakami Maru on the morning of August 3, 1981 in Tobata, one of the five industrial cities which incorporate Kita-Kyushu, Japan. Tobata is also the original headquarters of Nippon Suisan and the same building still houses the large trawling department of that company. Our voyage began with the trip through Kanmon Straits and we proceeded almost due east for the seamounts. During the run we were slowed for 2 days by high winds from one of the frequent typhoons of that time of year; but the weather at the Hancock Seamount proved uniformly sunny and calm throughout the fishing period. The passage out provided me with the opportunity to get acquainted with the crew and with the ship (see Appendix Table 1 for vessel and gear specifications and vessel personnel list). The Captain, Mr. Tamura, and Radio Officer Mr. Izumi, both spoke English well and with their assistance, my sampling duties went routinely and my stay aboard was made very enjoyable. I only regret being unable to offer a suitable explanation for the dearth of fish on the seamounts. It quickly became apparent that daytime trawling would yield no fish on either seamount. Extensive surveys and trial hauls were conducted over every bit of trawlable bottom without success. The vessel frequently fished through the night and

into the morning hours without taking more than a few kilograms of fish, although on occasion a concentration of armorhead would show on the echo sounder and several tons per haul would be taken for a short time. Often during nights of poor catches the recorders showed patches of fish just above the seamount or out off the edges where the bottom trawl was ineffective. The captain and officers were all experienced trawl fishermen (this was Captain Tamura's sixth year on the seamounts) and the gear of the Kitakami Maru was essentially the same as in previous seasons. There was no immediately apparent cause for the decline in abundance or concentration of these fish. The total catch of the target, incidental, and other species is given in Table 1. The area of operation is shown in Table 2 and Figure 1. The trawl catch by species and area is given in Table 3, and catch per unit effort data by area and species are presented in Table 4.

TRAWLING PROCEDURES[1]

Standard convex rectangular steel doors, 2 × 3 m in size are used to spread the opening of the trawl. The footrope length is 40 m and the cod end mesh size 90 mm (see Appendix Figure 1).[2] The main trawl cable is 30 mm steel wire; warp is let out to a length that is 2.5 times the depth. The seamount is surveyed with sonar and echo sounder prior to setting the trawl. The trawl is then deployed on an approach to the seamount, with a net sonde monitoring the opening of the net.[3] On both "C" and "J" Banks the net was towed across the seamount two or more times during one haul. The doors were brought up to the stern posts during the turn and let out again as the return approach was made. "K" Bank is a small and very sharply pointed pinnacle and the navigational difficulties involved in hitting this bank squarely necessitated single passes of only 5 minutes of bottom time per haul. Hang-ups were infrequent, occurring at spots which the echo sounders and sonar confirmed to be rough and hard. On several occasions armorhead were found concentrated in these troublesome locations.

SAMPLING PROCEDURES

I arranged to be called on the intercom phone when each haul was coming up. This gave me time to go up to the bridge to note the specifics of depth, times, etc., and arrive on deck or in the factory as the catch was dumped. I used my own estimations of catch weight, and checked them against the figures kept in the ship's log. The ship's figures were calculated using the factory count of the number of 10.5-kg freezer trays sent to the flash freezer from each haul, and worked back to whole catch weight by applying product-recovery ratios of 60% for armorhead and large

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[1]This has been discussed in reports by previous observers.

[2]Slides of the diagram used in constructing this net, and otter board specifications are on file at the Honolulu Laboratory, Foreign Vessel Observer Program (FVOP).

[3]Recorder paper from hauls made this season and copies of charts used by the Kitakami Maru are on file at the Honolulu Laboratory, FVOP.

Table 1.--Summary of total catch by species, Kitakami Maru.

Target Species

Common names	Pelagic armorhead, boarfish
Japanese name	Kusakari tsubodai
Scientific name	Pentaceros richardsoni Smith
Federal species code[1]	200
Product	Headed, gutted, and frozen in 21-kg cases
Season's catch, FCZ	208.5 metric tons (MT)
Total product	128 MT
Common name	Alfonsin
Japanese name	Kinmedai
Scientific names	Beryx splendens, B. decadactylus
Federal species code[1]	201
Product	Headed, gutted, and frozen in 21-kg cases
Season's catch, FCZ	15.7 MT
Total product	10.2 MT

Incidental Species
(Federal species code 499)[1]

Common name	Scientific names	Product
Mirror dory	Zenopsis nebulosa	Dressed, frozen (large only). Some consumed aboard.
(None)	Hyperoglyphe japonica	Dressed, frozen. Some consumed aboard.
(None)	H. japonica	Frozen whole in 21-kg cases.
(None)	Emmelichthyidae	Frozen whole in 21-kg cases.

Other Species

The remainder of the catch was waste species which were for the most part discarded. Individual crew members would dry flatfish in the rigging or save a handful of "red cod" for snacks. Miscellaneous species consumed probably totaled less than 50 kg for the trip.

Specimens of all incidental catch were photographed and frozen for systematic identification.

[1]See Federal Register 43(244):59301, Tuesday, December 19, 1978.

Table 2.--Area of operation.

Seamounts	Japanese designation	Position	
		Latitude N	Longitude E
Kinmei	"G" Bank	35°00'	171°45'
Milwaukee group	"F" Banks		
Yuryaku	"FC"	32°40'	172°15'
Kanmu	"FB"	32°15'	172°47'
South Kanmu	"FA"	32°02'	173°06'
Colahan	"E" Bank	31°00'	175°55'
Unnamed	"D" Bank	30°26'	177°28'
Fishery Conservation Zone			
Northwest Hancock	"C" Bank	30°16'	178°42'
Southeast Hancock	"J" Bank	29°48'	179°04'
Southeast Hancock	"K" Bank	29°40'	179°20'

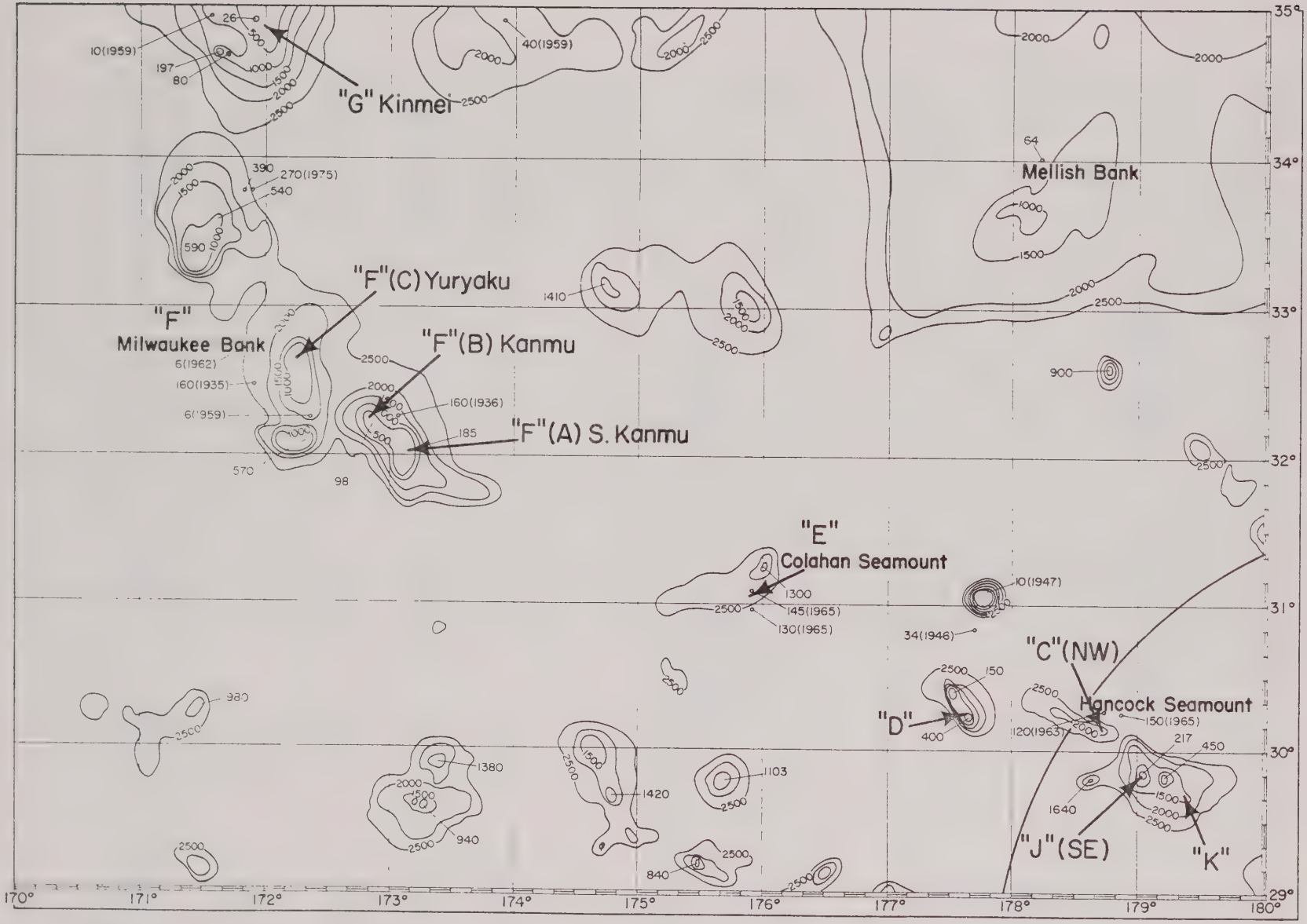


Figure 1.--Locations of seamounts and guyots northwest of the Northwestern Hawaiian Islands. Year of discovery is indicated for each guyot, and the 200-mile line is shown. Depths in fathoms.

Table 3.--Trawl catch by species and area (in metric tons).

Species	Northwest Hancock Seamount "C" Bank	Southeast Hancock Seamount "J" Bank	Southeast Hancock Seamount "K" Bank	All FCZ Banks
Armorhead	164.8	34.7	9.0	208.5
Alfonsin	5.8	8.6	3.6	18.0
Others[1]	8.7	7.3	1.3	17.3
Total	179.3	50.6	13.9	243.8

[1]Includes miscellaneous product as well as waste fish.

Table 4.--Catch per unit effort in kilograms/minute by area and species.

	Northwest Hancock Seamount "C" Bank	Southeast Hancock Seamount "J" Bank	Southeast Hancock Seamount "K" Bank	All FCZ Banks
Number of hauls	155	118	34	307
Total minutes trawling (includes turns off the seamount)	10,522	9,799	171	20,492
Armorhead				
Total catch (kg)	164,749	34,715	9,053	208,517
Kilograms/minute	15.66	3.54	52.94	10.18
Alfonsin				
Total catch (kg)	5,794	8,570	3,557	17,921
Kilograms/minute	0.55	0.87	20.80	0.87
Other species				
Total catch (kg)	8,739	7,248	1,330	17,316
Kilograms/minute	0.83	0.74	7.78	0.84
All species				
Total catch (kg)	179,331	50,593	13,940	243,864
Kilograms/minute	17.04	5.16	81.52	11.90

alfonsin, 50% for small alfonsin, and 100% for whole frozen fish. As there is no fish meal or oil facility on the Kitakami Maru, all heads, viscera, and waste fish are discarded. I felt that the ship's estimations of product/catch were very fair, and that basing catch volumes on factory figures (which are easily checked by the observer by simply counting the trays) is more accurate than "eyeballing" the gross catch either in the net or in the catch bin. While it would be difficult to quantify product recovery on specific individual fish, a daily or weekly check would be easy to arrange by weighing baskets of whole and processed fish during the season.

The single weakness noted in the ship's method of catch estimation was in estimating waste whole fish, which did not enter into product-recovery calculations. The crew shoveling waste fish into the discard conveyor or hoisting large sharks and rays overboard did not, to my knowledge, report any figures on these weights to the bridge. This is a fairly minor point considering the small proportion of unused catch on the seamounts.

Sampling for species composition, length, weight, and sex frequency was conducted by obtaining randomly chosen baskets of fish (15-30 kg per basket) as soon as the catch was dumped into the factory bin. On the second haul of each day and on other hauls of diverse species, these samples were sorted, counted, and weighed by species. On every haul, subsamples of approximately 30 fish were measured for fork length, and on at last one haul per day these fish were also individually weighed and sexed (Table 5). No otolith samples were taken.

Incidentally caught species were photographed and specimens frozen. Notes were kept on stomach contents, and armorhead were graded as to fat or lean body type. Very few extremely fat individuals were taken on the FCZ seamounts. As a result my original categories of "fat" and "lean" individuals seem to represent sex based differences rather than distinctly separate populations. It was only toward the end of the sampling period when we fished outside the FCZ that any really distinctly different groups were determined. In an attempt to quantify body "shape" of fat and lean armorhead, I marked each fish sampled as "+" or "-" in the margins of the length/weight/sex form, and tabulated grams body weight per millimeter fork length.

In addition, 50 fat and 50 lean specimens from each of three seamounts were brought back to the Honolulu Laboratory for further analysis.

REMARKS

Throughout the fishing period Northwest Hancock ("C" Bank) yielded consistently larger catches and larger individual fish than did Southeast Hancock ("J" Bank). "K" Bank on Southeast Hancock seemed to have larger fish than "J" Bank on the same seamount, although samples at "K" Bank were restricted by the comparatively few hauls made there. Alfonsin made up only 18% of the total catch, and thus equaled all other incidentals in

Table 5.--Summary of biological observations on armorheads and alfonsins.

	Northwest Hancock Seamount "C" Bank	Southeast Hancock Seamount "J" and "K" Banks	All FCZ Banks combined
Armorheads (Total number of fish sampled: 4,869)			
Average fork length (mm)	303	299	302 (range: 262-420)
Average weight (kg)	0.52	0.49	0.51 (range: 0.21-1.70)
Sex ratio (% male:% female)	46:54	39:61	43:57
Body type ratio (% fat:% lean)	67:33	61:39	60:40

	Northwest Hancock Seamount "C" Bank	Southeast Hancock Seamount "J" Bank	Southeast Hancock Seamount "K" Bank	All FCZ Banks combined
Alfonsins (Total number of fish sampled: 2,480; size range: 155-457 mm, 0.8-2.3 kg)				
Average fork length (mm)	275	188	316	
Large fish				321
Small fish				175
Average fish weight (kg)	0.62	0.22	0.74	
Large fish				0.61
Small fish				0.22
Sex ratio (% male:% female), large fish only				62:38

Japan Fisheries Agency.
1974. Survey of the North Pacific seamounts (Kita Taiheiyō kaizan chōsa). Report of Kaiyo Maru survey cruises, 1972 season, 136 p. (Engl. transl. of selected portions of the report by T. Otsu, 1981, 55 p., Transl. No. 54; available Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.)

Japan Marine Fishery Resource Research Center (JAMARC).
1973. Surveys of trawling grounds in the north central Pacific Ocean, 1972 season (Showa 47-nendo kaigai torōru shingyojyo kigyōka chōsa hokokusho--Hokubu chūo Taiheiyō kaiiki). JAMARC Rep. 7, 89 p. (Engl. transl. of portions of the report by T. Otsu, 1977, 27 p., Transl. No. 19; available Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.)

Sasaki, Takashi.
1978. The progress and present status of the seamount fishing ground development program (Kaizan gyojyō kaihatsu no keika to genjō). Bull. Jpn. Soc. Fish. Oceanogr. 33:51-53. (Engl. transl. by T. Otsu, 1979, 6 p., Transl. No. 35; available Southwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96812.)

Appendix Table 1.--Vessel and gear specifications and personnel.

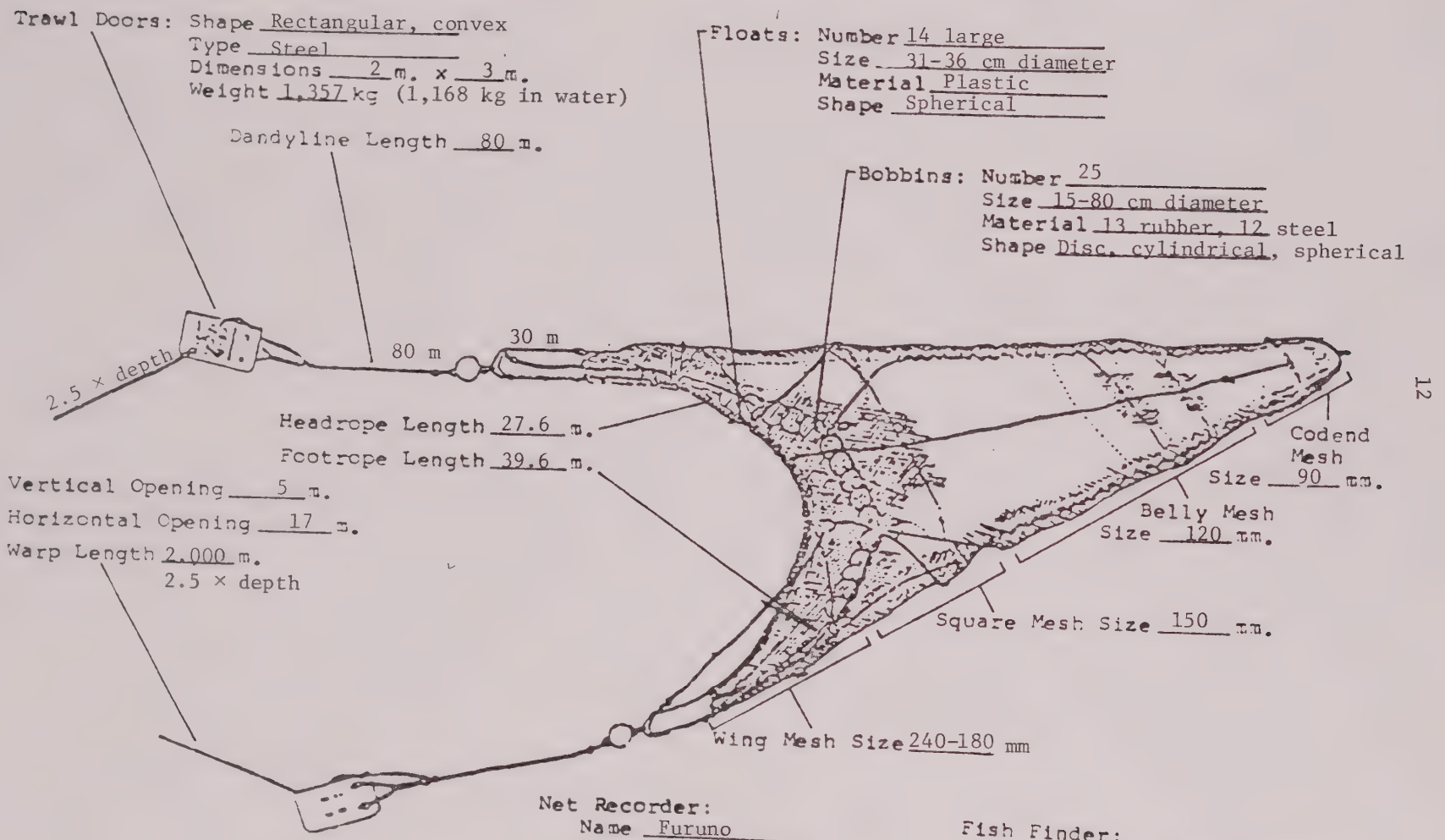
Vessel		
Permit number	JA-81-0321-B	
Length	56.6 m	
Gross tonnage	549.86 short tons	
Net tonnage	215.92 short tons	
Width	9.20 m	
Draft	3.80 m	
Engine type	Diesel, 6 cylinders	
Fuel consumption	3 kl/day fishing, 4 kl/day running	
Horsepower	1,500	
Hull number	100765	
Registration number	F01-132	
Company/owner	Nippon Suisan Kaisha, Ltd.	
Vessel type	Freezer-factory, independent stern trawler	
Year launched	1966	
Port of registry	Tokyo, Japan	
Home port	Tobata, Kita-Kyushu, Japan	
Radio call sign	JMLB	
Gear		
Net dimensions	(See Appendix Figure 1)	
Door measurements	2 × 3 m	
Main trawl winch	Electric, 180 kW	
Total wire on drum	2,000 m	
Flash freezer capacity	Approximately 3 tons	
Processing speed	Approximately 1.5 tons/hour	
Personnel (35 total ship complement)		Prior experience in seamount fishery
Captain	Mr. Tomiyasu Tamura	6 seasons
Radio Officer	Mr. Kazuo Izumi	None
Navigation Officers	3	3 seasons
Engineers	3	None
Galley	3	None
Oilers	4	?
Deck and processing crew	19	?

Appendix Figure 1.--Description of trawl gear used on the Kitakami Maru.

NET DIMENSIONS AND CHARACTERISTICS

Type of Vessel Japanese independent stern trawler

Observation Period August 3-October 5, 1981



Net Recorder:
Name Furuno
Model Number FNR 50
Frequency
Sound frequency: 200 kc/sec
Transmitting frequency: 50 kc/sec
Transmitting range: 2,000 m

Fish Finder:
Name JRC zoom echo sounder
Model Number NJA 330
Frequency 28, 75, and 200 kHz
Paper Type - Wet x Dry
Speed of Advance 12 mm/sec

81-10

National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

PLANNING DOCUMENT FOR THE ASSESSMENT OF MARINE RESOURCES AROUND GUAM AND THE COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

by

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December 1981

INTRODUCTION

Guam and the Commonwealth of the Northern Mariana Islands (CNMI) consist of a chain of 25 volcanic islands arranged in an approximately north-south axis 450 nmi long (Figure 1). The total land area of these islands is 370 nmi^2. To the west of these islands and within the U.S. Fishery Conservation Zone (FCZ), there are numerous seamounts. To the southeast of the chain is the Mariana Trench where a depth of almost 6,000 fathoms has been recorded.

The waters around Guam and CNMI are rich in marine resources and historically some of these resources have been commercially fished. There is, however, a need for a comprehensive assessment of the abundance and commercial potential for the marine resources in this region to aid local governments to develop local fisheries, to serve as baseline information for mainland U.S. interests in determining whether to invest in fishery projects in the area, and to provide data to the Western Pacific Regional Fishery Management Council (WPRFMC) in their development of management plans as mandated by the Magnuson Fishery Conservation and Management Act (MFCMA).

The geographic area covered by the program is the FCZ around Guam and the CNMI. The major objectives of the program in order of priority are to:

1. Determine resources of commercial potential;

2. Estimate the magnitude, range, and seasonal variation in availability and abundance of these resources;

3. Estimate their probable levels of sustained harvest; and

4. Add to the knowledge of the biology of the region.

POTENTIAL RESOURCE GROUPS

To date there have been four resource survey cruises by the NOAA vessel Townsend Cromwell and two cruises of a charter boat, FV Typhoon, on which at least a portion of the time was spent in the Guam and CNMI region.

The results from these cruises along with some commercial catch information are reported in Uchida and Eldredge.[1] Based on these data, the principal species groups in the Guam and CNMI region are assigned rankings based on their relative commercial or potential commercial values (Table 1). From Table 1 four species groups are identified as having considerable commercial or potential commercial value. These species groups are tunas, mackerels (bigeye scad), bottom fishes (snappers and groupers), and deep-water shrimps.

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[1]Uchida, R. N. and L. Eldredge. Manuscr. in prep. Summary of environmental and fishery information of Guam and the Northern Mariana Islands.

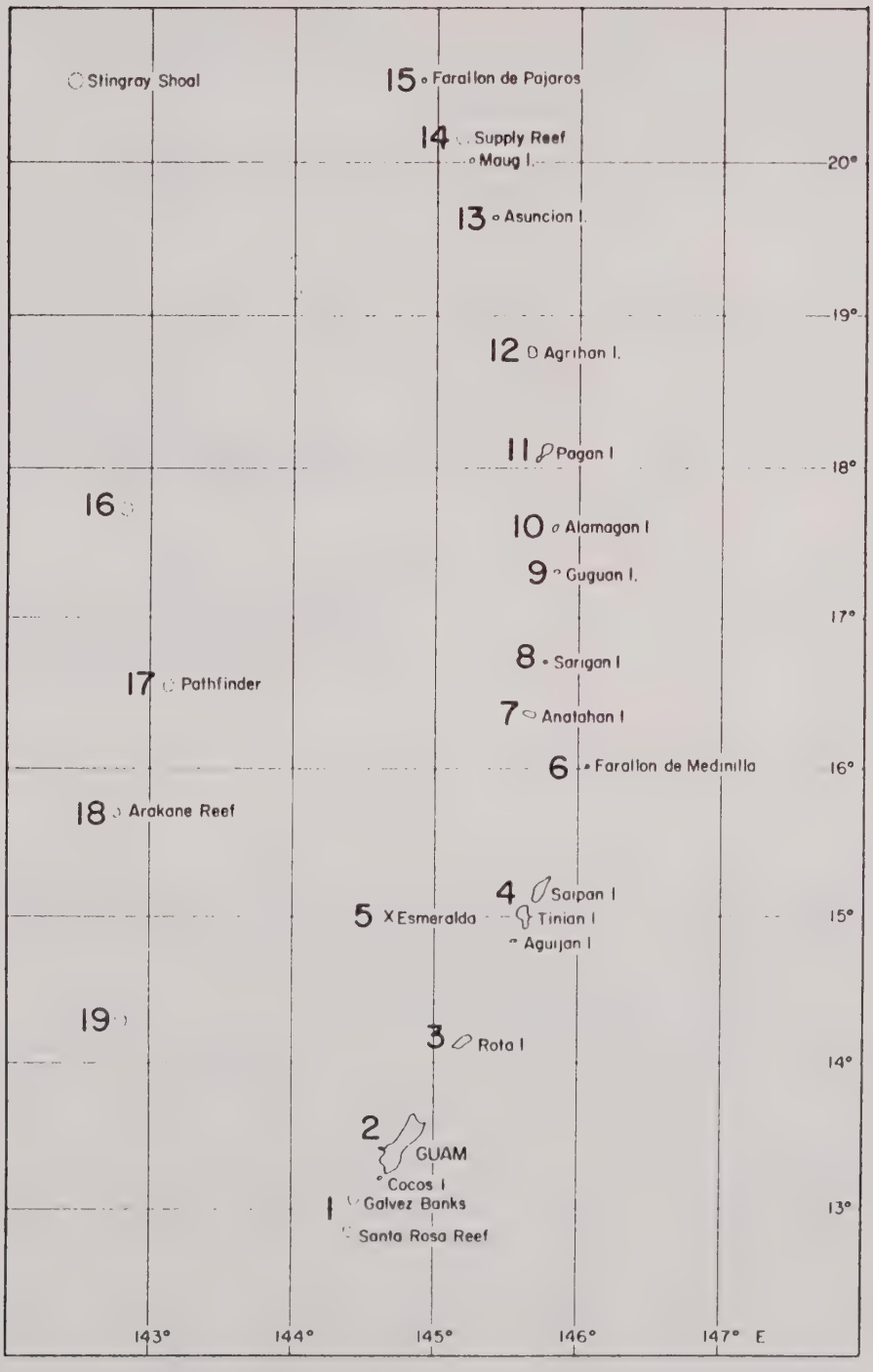

Figure 1.--Sampling areas.

Table 1.—Priority of species for the National Marine Fisheries Service sampling program (L = low, M = medium, and H = high).

Species	Relative potential economic value of resource	Relative importance to local subsistence fishery
Lobsters and crabs	L	L
Reef fishes	L	H
Baitfish (piha)	L	L
Octopus	L	L
Snappers and groupers	M-H	L
Jacks, Caranx sp.	M	M
Alfonsin, Beryx sp.	L-M	L
Mackerel scad, Decapterus spp.	L	L
Bigeye scad, Selar; Trachurops	M-H	H
Mackerel, Scomber japonicus	L	L
Squid	L	L
Shrimp	M-H	L
Rainbow runner, Elagatis bipinnulata	M	M
Yellowfin tuna, Thunnus albacares	H	M
Skipjack tuna, Katsuwonus pelamis	H	M
Kawakawa, Euthynnus affinis	L	L
Turtles and whales	L	L
Sharks	L	L
Others	L	L

The tunas are a resource of proven value and are currently fished by foreign bait boats and longliners. As an indication of the abundance of tunas in the area, in 1977 Japanese bait boats and longliners caught 8,870 metric tons (MT) of tunas in the FCZ around Guam and CNMI. There is considerable detailed catch and effort data from the Japanese bait boats and longliners, and it would be pointless to have the Townsend Cromwell undertake any general sampling for tunas. However, it would be extremely interesting to undertake a limited amount of sampling to locate sites with potential for a night handline fishery for tunas similar to the Hawaiian ika-shibi fishery. The Hawaiian night handline fishery off the island of Hawaii is conservatively estimated at $2-$3 million annually. The yellowfin tuna is one of the principal species in the Hawaiian night handline fishery. The Japanese longline catch of this species south of Guam, is very comparable to that of Japanese longliners off the island of Hawaii, indicating the resource for a night handline fishery off Guam exists. The night handline tuna fishery would be ideal for the Guam and CNMI region because it is neither labor nor capital intensive and Guam has excellent air shipping schedules to the Japanese market. However, to date, a night handline fishery has not developed in Guam because productive fishing grounds have not been found.

The akule or bigeye scad, Trachurops crumenophthalmus, (called atulai in Guam) is probably second in commercial importance after tunas for the Guam and CNMI area (Uchida and Eldredge, footnote 1). The Guam Aquatic and Wildlife

Resource Division reported that the estimated catches from inshore runs around Guam in 1979 was 15 MT. The Townsend Cromwell 1978 survey found that akule occurs in substantial numbers in waters around the high islands and over the offshore seamounts and banks. Sampling for akule from the Townsend Cromwell will employ night lights and handlines to estimate relative abundance throughout the chain. In addition aerial survey methods will also be employed on several occasions to obtain "instantaneous" estimates of akule biomass around the islands and over the banks.

Fishes of the snapper and grouper complex have been caught in good numbers around the high islands and over the seamounts. Species which appear most abundant include: onaga, Etelis carbunculus; lehi, Aphareus rutilans; an unidentified grouper, Epinephelus sp.; black carangid, Caranx lugubris; gindai, Rooseveltia brighami (= Pristipomoides zonatus), yellowtail kalikali, P. auricilla; ehu, Etelis marshi; pink kalikali, P. sieboldii, and yellow-eye opakapaka, P. flavipinnis. On one cruise during a total of 16 days of fishing around seven high islands in the CNMI, the FV Daikatsu Maru caught 8.5 MT of bottom fishes (Uchida and Eldredge, footnote 1).

Sampling gear for the bottom fishes will be bottom handlines. In addition to sampling to estimate relative abundance, intensive fishing at a small isolated pinnacle and a follow-up of the intensive fishing which occurred in 1967-68 at Haputo Pinnacle off Guam reported in Ikehara et al.[2] will be undertaken to estimate absolute abundance.

There are two species of deep-water shrimps which have been trapped in waters around Guam and CNMI. Hetercarpus ensifer is typically found in depths from 100 to 400 fathoms, and H. laevigatus is typically found between 250 and 600 fathoms (Uchida and Eldredge, footnote 1). There are three banks, Galvez Banks, south of Guam; Esmeralda Bank, west of Tinian; and what appears to be a large but poorly charted bank around Farallon de Medinilla north of Saipan, plus the banks around the islands of Guam, Saipan, and Tinian which in total may contain as much as 1,500 nmi^2 of shrimp habitat. These and other banks and seamounts will be sampled with wire-mesh traps.

SAMPLING SCHEME

Relative Abundance

The target species for our relative abundance survey will be bottom fishes, shrimps, and mackerels. Our unit of measure of relative abundance will be catch per unit effort (CPUE) based on a fixed or constant fishing effort. For example, our measure of relative abundance of bottom fish will be CPUE computed on the basis of four lines fishing for 1 h. At a given location, we may have several hours of fishing with four lines and in this case, we will compute a CPUE based on the first hour of fishing, another CPUE based on the second hour, and so forth. We will use these multiple CPUE

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[2]Ikehara, I. I., H. T. Kami, and R. K. Sakamoto. 1970. Exploratory fishing survey of the inshore fisheries resources of Guam. Proc. 2d CSK Symp., Tokyo, p. 425-437.

values at a given site as replicates. The principal reason for computing CPUE values on a constant amount of fishing effort is that the variance of the CPUE estimate is inversely proportional to the amount of effort. If CPUE estimates are all based on the same amount of effort, then comparisons of CPUE between sites and seasons can be performed with an ANOVA model, because the assumption that the observations have equal variances should be satisfied.

Our sampling scheme to chart relative abundance consists of a systematic sample possibly followed by a stratified sample applied to regions of commercial potential if additional precision is required. In many sampling programs, the goal is to estimate a single population parameter, e.g., the proportion of the population that will vote for a specific candidate. In a stock assessment survey where we know that the abundance is heterogeneous, the mean population catch rate is of little value. More important is a chart of the distribution of abundance or relative abundance over the geographic region covered by the survey. In this case, the usual sampling approach such as a simple random sample or stratified random sample is not as efficient as a systematic sample. In systematic sampling, events are sampled in a regular fashion.

In our situation, the geography of the region suggests 19 distinct sampling areas consisting of 6 reefs and seamounts and 13 islands (Figure 1). A 5-day sampling scheme has been developed to collect sufficient data necessary for shrimp, bottom fish, and akule abundance and yield estimation (Table 2). The first field survey period for the Townsend Cromwell is scheduled to run from mid-March through August 1982. During this period the Townsend Cromwell will undertake a 22-day bathymetric cruise followed by 3 biological cruises of approximately 40 days each. These three biological cruises will enable us to sample each island/seamount once for 5 days. (Guam, Saipan, and Farallon de Medinilla due to their area will be sampled for 8 rather than 5 days.) In addition, two areas, Pagan Island in the upper part of the chain and Esmeralda Bank in the lower part, will be sampled on each of the three cruises to provide an estimate of the variation in CPUE over the 5-month survey period.

The Townsend Cromwell cruise schedule is given in Table 3. Tentative cruise tracks are given in Figures 2, 3, and 4.

After the completion of the systematic sampling program, regions of abundance sufficient for commercial exploitation will be identified and subsequent sampling in these regions during the following survey period may be undertaken to improve the physical definition of these regions and reduce the variance of our CPUE estimates.

Yield Estimates

Several approaches will be used to determine yield estimates. If there is a record of commercial catch and effort statistics for a resource, then production analysis based on a regression of CPUE against effort will be used to estimate sustainable yield and the corresponding fishing effort. For bottom fishes, shrimps, and possibly mackerels, if there are no commercial catch and effort data, then we will conduct intensive fishing experiments at small and isolated geographic sites and use the Leslie method based on the

Table 2.--Sampling task itinerary for bank or seamount.

Day 1 -	Arrive at bank Handline for bottom fishes Set shrimp traps Night handline for akule
Day 2 -	Handline for bottom fishes Recover and reset shrimp traps Night handline for tunas
Day 3 -	Handline for bottom fishes Night handline for akule
Day 4 -	Handline for bottom fishes Set shrimp traps Night handline for akule
Day 5 -	Recover shrimp traps Troll to next sampling area (island/seamount)

Table 3.--Cruise schedule for Townsend Cromwell for FY 1982.

February 6 to 19	- Transit to Honolulu	14 days
February 20 to 22	- In port	
February 23 to 25	- Shakedown cruise	3 days
February 26 to 28	- In port	
March 1 to 18	- Transit to Guam	18 days
March 19 to 22	- In port, Guam	
March 23 to April 13	- Bathymetric cruise	22 days
April 14 to 16	- In port	
April 17 to May 7	- Biological cruise I-A	21 days
May 8 to 10	- In port	
May 11 to 30	- Biological cruise I-B	20 days
May 31 to June 2	- In port	
June 3 to 22	- Biological cruise II-A	20 days
June 23 to 25	- In port	
June 26 to July 17	- Biological cruise II-B	23 days
July 18 to 20	- In port	
July 21 to August 5	- Biological cruise III-A	16 days
August 6 to 8	- In port	
August 9 to September 3	- Biological cruise III-B	25 days
September 4	- In port	
September 5 to 22	- Transit to Honolulu	18 days
		200 days

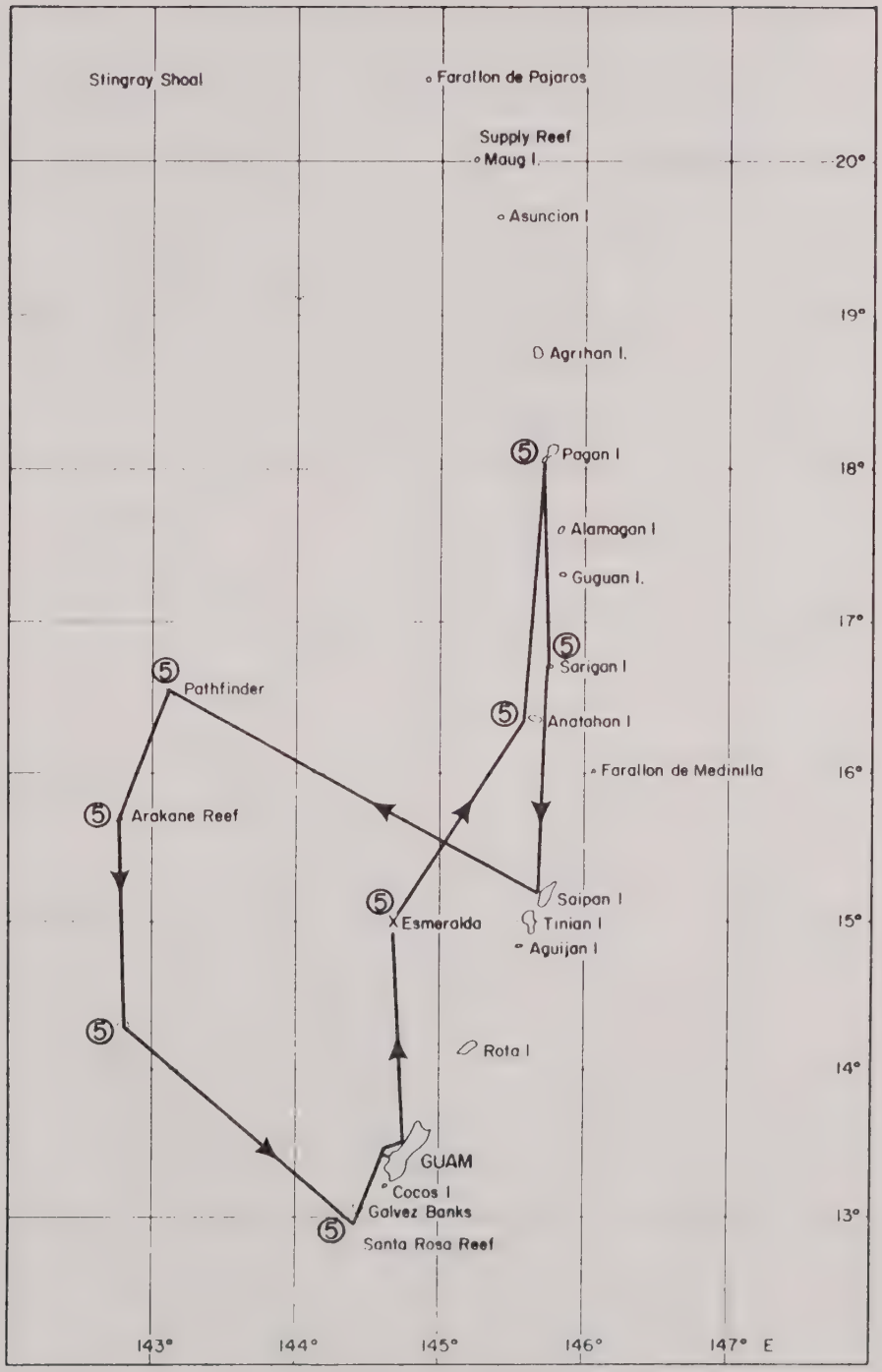

Figure 2.--Biological cruise 1-A = 21 days
1-B = 20 days
(5) indicates number of days sampling.

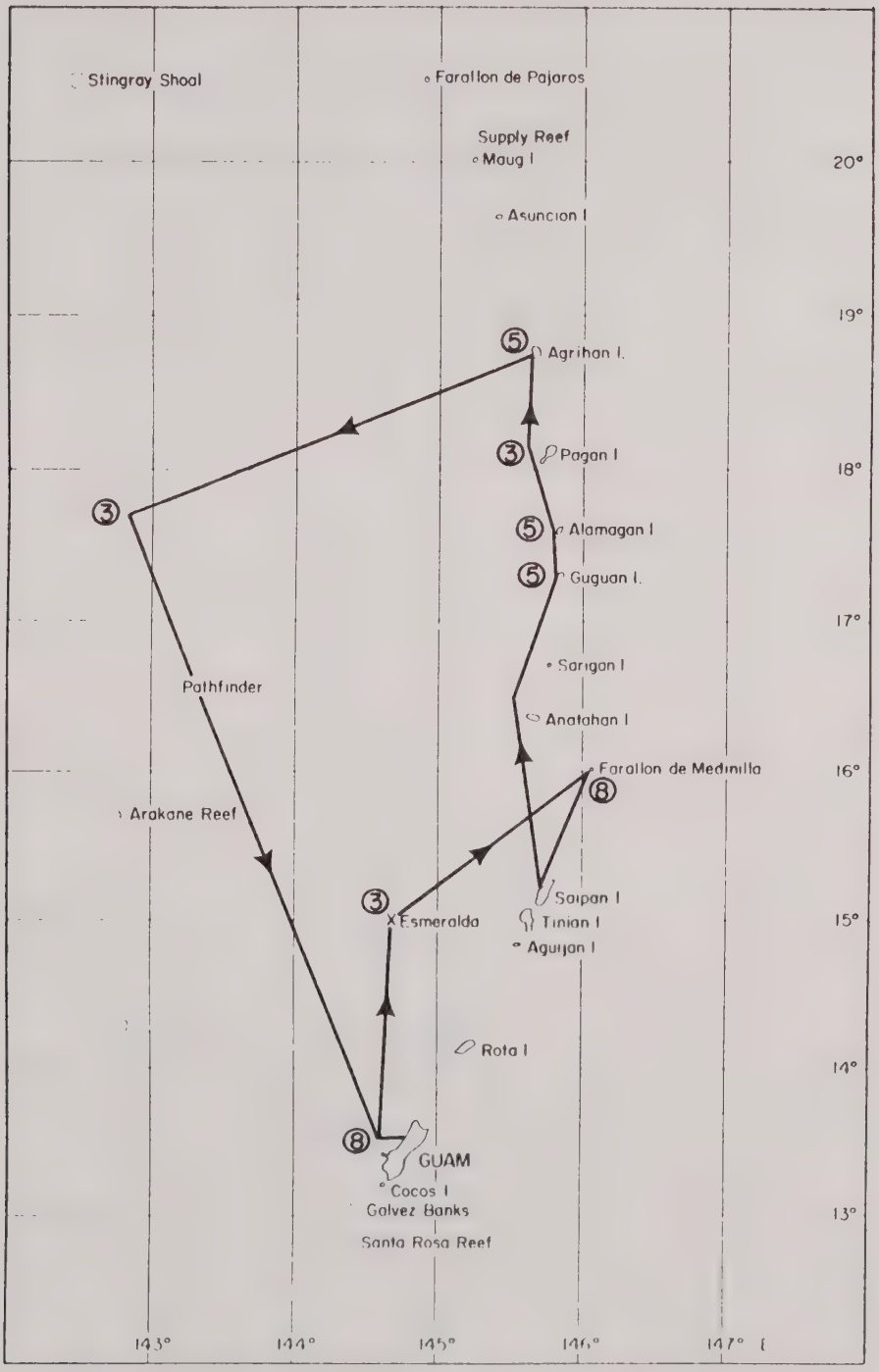

Figure 3.--Biological cruise II-A = 20 days
II-B = 23 days
(5) indicates number of days sampling.

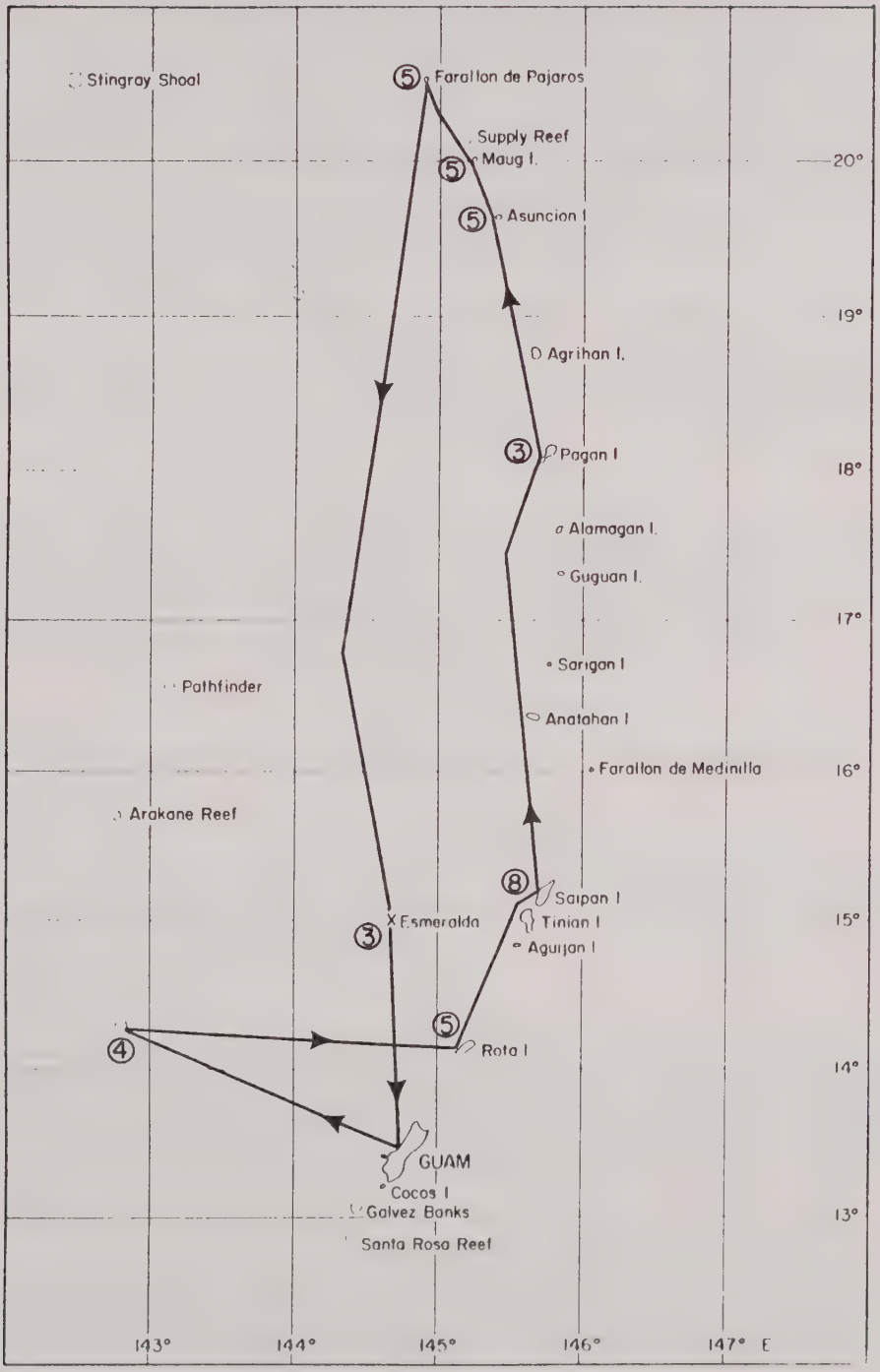

Figure 4.--Biological cruise III-A = 16 days
III-B = 25 days
(5) indicates number of days sampling.

regression of CPUE against cumulative catch to estimate catchability and initial biomass. We can convert the initial biomass to a density estimate by dividing the biomass by either the length of an appropriate depth contour or the area of habitat to obtain, for example, kilograms of bottom fish per kilometer of 100-fathom contour, or kilograms of bottom fish per square kilometer. We can use the correspondence between CPUE and density at the intensive fishing site to estimate density and, subsequently, biomass at all the regions, where relative abundance (CPUE) estimates have been obtained. For example, if we wish to determine density at some site "A" based on a CPUE at site "A," then:

$$\text{Density of site "A"} = \left[\begin{array}{l}\text{Density at}\\ \text{intensive}\\ \text{fishing site}\end{array}\right] \times \left(\frac{\text{CPUE at site "A"}}{\text{CPUE at intensive fishing site}}\right).$$

Typically estimates of biomass and catchability will not be sufficient to estimate sustainable yield. However, given estimates of virgin biomass (B_o) for stocks of bottom fishes, shrimps, and mackerels estimated from intensive fishing experiments, an estimate of the maximum yield (C_{max}) from these stocks can be obtained from either Gulland's relationship:

$$C_{max} = 0.5 \times M \times B_o$$

where M is the instantaneous natural mortality or from Pauly's[3] relationship:

$$C_{max} = 2.3 \times \left(\omega^{-0.26}\right) \times B_o$$

where ω is the mean of the weight at first maturity and the maximum weight of the fish in the stock (in grams).

Data To Be Collected

The existing bathymetric data for the survey region are limited. Many banks are poorly charted and in some cases the existence of some seamounts is uncertain. The survey program will begin with an initial cruise of 22 days to obtain the bathymetric data for important seamounts and banks around Guam and Saipan. Some hydrographic data will also be collected on this cruise.

After this initial cruise the biological sampling will begin in accordance with the previously defined sampling program. The data to be collected for each species group are indicated in Table 4. The specific itinerary of a 5-day sampling program at a bank or seamount is given in Table 2.

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[3]Pauly, D. 1981. Studying single-species dynamics in a tropical multispecies context. Paper prepared for ICLARM/CSIRO Workshop on the Theory and Management of Tropical Multispecies Stocks, 12-23 January 1981, Cronulla, Australia, 65 p.

Table 4.—Data to be collected by species groups.

SHRIMPS

1. CPUE data to estimate relative abundance by bank, depth, and season.
2. Length-frequency data at specific sites over time to estimate growth curves and subsequently mortality.
3. Morphometric and fecundity data.

BOTTOM FISHES

1. CPUE data to estimate relative abundance by bank, depth, and season.
2. Length-frequency data at specific sites over time to estimate growth curves and subsequently mortality.
3. Intensive fishing CPUE data to estimate absolute biomass.
4. Morphometric and fecundity data.

TUNAS

1. Night handline CPUE data by bank to locate sites of ika-shibi potential.

MACKERELS

1. CPUE data to estimate relative abundance by bank and season.
2. Length-frequency data to estimate growth and mortality.
3. Tagging results to estimate migration.
4. Morphometric and fecundity data.

OTHER SAMPLING AS TIME PERMITS

1. Tangle nets and inshore diving to sample for lobsters.
2. Bottom gill nets for bottom fishes.

THE DATA MANAGEMENT SYSTEM

The data system for the storage and analysis of the survey data is presented schematically in Figure 5. The heart of the system is the Statistical Analysis System (SAS)[4] files which are based on a packaged software system supported by the University of Hawaii IBM 370 for data base management. These SAS files enable data entered and stored in one format to be subsetted or re-formated and used in subsequent analyses. After each cruise computer-generated charts of relative abundance for each species sampled will be produced and survey summaries will be generated to insure that the data collected are reviewed and available for any revisions which may be necessary in the sampling plan. Data from the SAS files will also be used for specific analysis such as morphometric and growth curve analysis.

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[4]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

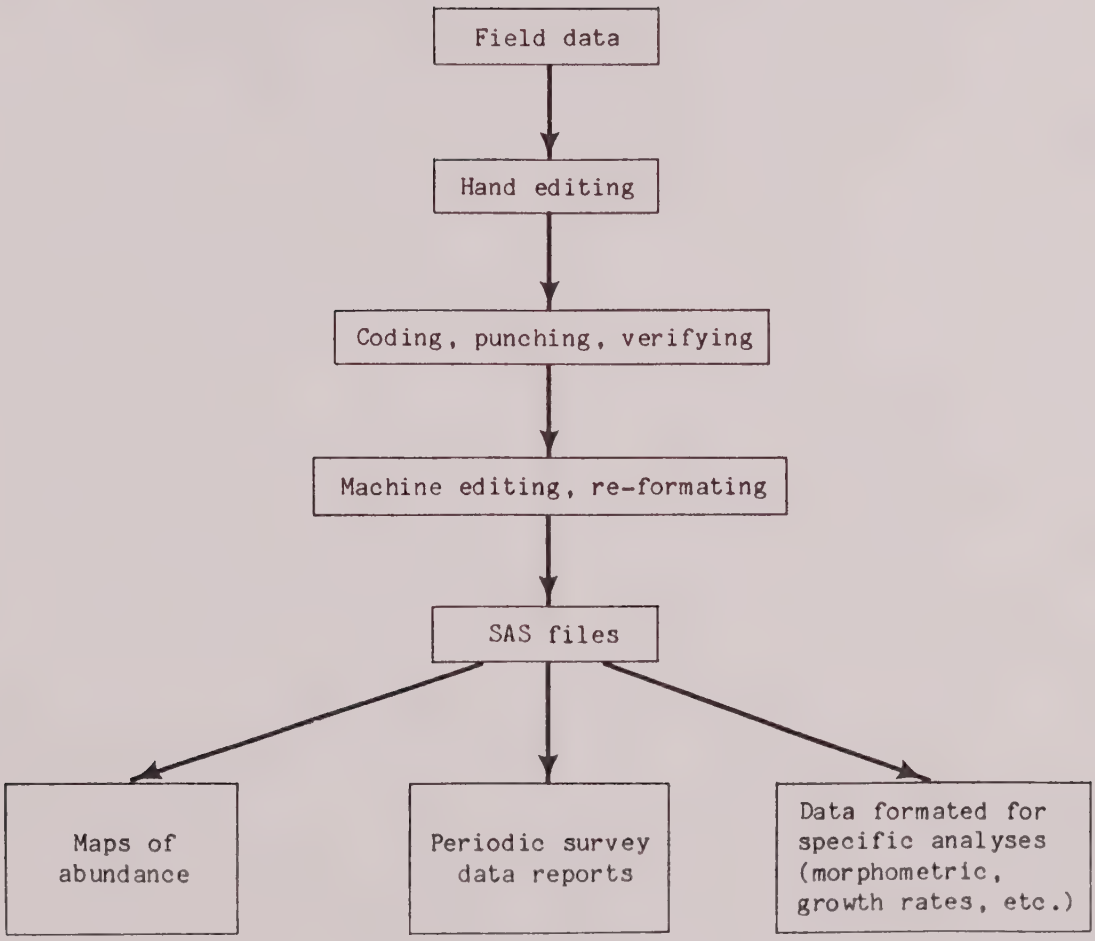

Figure 5.—Schematic of data base system for sampling data.

A PLAN FOR CIGUATERA RESEARCH IN THE PACIFIC

PREPARED BY THE

HONOLULU LABORATORY
SOUTHWEST FISHERIES CENTER
NATIONAL MARINE FISHERIES SERVICE, NOAA
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ADMINISTRATIVE REPORT H-81-11
DECEMBER 1981

EXECUTIVE SUMMARY

The Problem

Ciguatera, a disease characterized by gastrointestinal and neurological symptoms caused by the ingestion of a variety of tropical marine reef fishes, is a long-standing problem in the many tropical and subtropical islands in the Pacific. Ciguatera spread to Hawaii and other central Pacific islands in the 1940s and the public health records show periodic outbreaks of the disease in Hawaii ever since.

The Program

What: The Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, NOAA proposes a multidisciplinary study of the ciguatera problem to solve the various (ecological, public health, pharmacological, etc.) problems associated with ciguatera.

Where: Field research will be carried out in various geographic locations in the Pacific, including the Hawaiian Archipelago, where ciguatera outbreaks may occur.

Who: Over the years many researchers in various disciplines have been working on the ciguatera problem in the Pacific. The program will continue to be a multidisciplinary effort and will involve scientists at the Honolulu Laboratory, various departments of the University of Hawaii, the Tohoku University of Japan, the Hawaii Department of Land and Natural Resources, and other research agencies.

How: Three overall objectives for ciguatera research were identified. A total of 22 research activities and subprojects were developed to achieve the objectives.

Goals and Objectives

The three overall objectives for ciguatera research are (1) to be able to "manage" the ecosystem, i.e., to predict the potential outbreak of ciguatera and to possibly interrupt the chain of events leading to potential outbreaks, (2) to develop a treatment for human ciguatera intoxication, and (3) to develop and implement a simple "dipstick" test for ciguatoxin and other toxins that can be used by laymen.

A PLAN FOR CIGUATERA RESEARCH IN THE PACIFIC

Ciguatera intoxication is a long-standing problem in many tropical and subtropical islands of the Pacific. Ciguatera is a disease characterized by gastrointestinal and neurological symptoms which are caused by the ingestion of any one of a variety of tropical marine reef fishes. It is evident that ciguatera outbreaks have occurred in oceanic islands of many areas in the Pacific Ocean at least as long as records exist from these areas and furthermore, it is likely that the Pacific islanders knew of the toxicity of fishes long before the beginning of European exploration in the Pacific. In more recent years, various researchers have pointed out the significance of ciguatera on the health of island populations in the Pacific. For example, one of the highest incidence of ciguatera intoxication on record occurred in the island of Hao in the Tuamotu Archipelago, where out of 514 individuals interviewed 224 (43%) reported that they had been intoxicated at least once.

The islands in the central Pacific including the Line Islands, Johnston Island, and the Hawaiian Archipelago apparently were free of ciguatera until about the 1940s. In response to the spread of ciguatera to these areas, beginning in the late 1950s to early 1960s a broad research program was undertaken by the Hawaii Institute of Marine Biology, University of Hawaii, in the chemical isolation, identification, pharmacology, and biological origin of the toxin or toxins causing ciguatera, as well as an epidemiological study of ciguatera intoxication in the Pacific. Much progress has been made to resolve the various facets of the ciguatoxin problem by the researchers at the Hawaii Institute of Marine Biology and other research groups at the University of Hawaii, as well as researchers at other laboratories throughout the Pacific.

The earliest work on the chemistry of the toxin began in the early 1940s and involved studies on its solubilities and other characteristics. It was noted that the toxin could be removed from fish flesh with ethanol and that the toxin was heat stable. Work on the chemistry of ciguatoxin--the name used for the agent responsible for ciguatera beginning in 1967--advanced to a point where the basic empirical formula $(C_{35}H_{65}NO_8)_n$ is now known. It was also determined that ciguatoxin "is apparently a lipid containing quaternary nitrogen, hydroxyl, and carbonyl functions."

Regarding the origin and transmission of toxin, the idea that ciguatoxin is endogenous in the fish, similar to tetrodotoxin in puffers, was early rejected. Researchers quickly recognized that ciguatera is of biological origin and is caused by a toxin that arises in the environment. The theory of the biological origin of the toxin or the food chain theory, was best advanced as early as 1958 that the original elaborator of the toxin was likely to be an "alga, a fungus, a protozoa, or a bacterium." In 1971, conclusive support for this theory became available with the discovery of ciguatoxin, or a compound which was indistinguishable from it at that time, in the gut viscera and flesh of a surgeonfish, Ctenochaetus striatus, which is a detrital feeder that cannot bite off pieces of attached algae. A breakthrough in this aspect of ciguatera research occurred in 1977-78 by the discovery of a new benthic dinoflagellate, Gambierdiscus toxicus, which was associated with the occurrence of ciguatoxin (and mitotoxin) in algal/detrital mixtures believed to be the causative agent in ciguatera outbreaks.

Subjective assays or tests for toxins by the use of laboratory animals began in the early 1940s. Toxicity tests by injections of aqueous extracts from potentially toxic fish were also initiated in the early 1940s. The standard technique of using mongooses in feeding tests was developed at the Hawaii Institute of Marine Biology in 1960. In 1977, in another breakthrough, "a practical, sensitive, simple, and relatively specific radioimmunoassay test for the assay of ciguatoxin directly from natural sources" was developed.

It is evident that much has been done in solving the long-standing ciguatera problem. It is also evident that much still remains to be done. Presently a number of research organizations in Hawaii are actively working on various aspects of the ciguatera problem. While there has been an exchange of results and views among some of the ciguatera researchers, the need for a workshop to bring together these active investigtors for an in-depth discussion of the problems appeared warranted. In the spring of 1981 (March 18-20) the "Hawaii Ciguatera Workshop," sponsored by the Honolulu Laboratory and University of Hawaii Sea Grant, was held at the Honolulu Laboratory (Appendix A). The objective of the workshop was to develop working hypotheses to guide future research on the ciguatera problem. Some of the goals of ciguatera research are to fully understand the mechanism underlying the origin and transfer of the toxin(s) in the ecosystem and to determine if corrective measures can be developed to safely provide fish for human consumption. Considering earlier research and the status of ongoing research on the ciguatera problem, the workshop participants identified three basic goals and objectives for future ciguatera research. Also a total of 22 research projects/activities relating to the three goals/objectives were identified. The relationships of the research activities/subprojects and objectives are shown in Figure 1. The objectives and research activities/subprojects are described below.

OBJECTIVES

I. To obtain an understanding of the factors or mechanisms triggering the chain of events in the reef ecosystem leading ultimately to outbreaks of ciguatera intoxication in the human population so that the "management" of the ecosystem will be possible.

II. To elucidate the pharmacological aspects of ciguatera intoxication and to develop a viable treatment for human ciguatera intoxication.

III. To develop and disseminate for general use a quick and reliable field test to screen marine organisms for ciguatoxin and related toxins.

DESCRIPTION OF RESEARCH ACTIVITIES AND SUBPROJECTS

1. Monitor public health records

The Hawaii Department of Health maintains records on local outbreaks of ciguatera cases including the date and site of the outbreak, the species of fish implicated, and where it was caught. The data from these documented cases of ciguatera intoxications will be used to plan biological sampling of the reef habitat where the implicated fish was caught.

2. Sample substrate for dinoflagellates

The benthic dinoflagellate, G. toxicus, has been determined to be the source of ciguatoxin in the coral reef ecosystem. Based on current records of ciguatera outbreaks maintained at the Hawaii Department of Health, the coral reef habitat where fishes implicated in ciguatera outbreaks were caught will be sampled for the presence of G. toxicus.

3. Determine environmental conditions in dinoflagellate "bloom" and "no-bloom" areas

Data on environmental variables will be collected in dinoflagellate "bloom" and "no-bloom" areas to obtain baseline information for comparisons of environmental conditions in these areas.

4. Field and laboratory studies on transfer of toxin in food chain

Detailed field and laboratory studies to determine the transfer of ciguatoxin and other toxins from dinoflagellates to the fish carnivores in the reef ecosystem will be carried out.

5. Determine factors producing toxic dinoflagellate blooms

Analyze data collected in subproject 3 to determine environmental conditions producing toxic dinoflagellate blooms. A comparison of environmental conditions between areas with and without toxic dinoflagellate blooms should provide clues as to causative factors.

6. Determine best procedure to test for toxins in the marine environment

Instead of testing fish for the presence of toxins, it may be preferable to determine the presence of toxins at an earlier stage in the transfer of toxins in the marine environment. Studies should be conducted to determine the feasibility of testing for toxins at various stages of toxin transfer in the ecosystem.

7. "Manage" ecosystem (predict and interrupt chain of events leading to possible ciguatera outbreaks)

Analyze data to allow the prediction of potential ciguatera outbreaks and possibly to disrupt the chain of events to prevent ciguatera outbreaks in the human population.

8. Determine source of toxins

Ciguatoxin and other toxins are found in minute quantities in the flesh and viscera of fishes. Toxicity of fishes may vary with season and with species. Consequently large amounts of toxic fish are needed to extract only a small amount of toxin. Effort will be expended to locate highly toxic fish for the extraction of ciguatoxin and other toxins.

9. Obtain source of toxins

Once sources of toxic fish are located, attempts will be made to collect enough of them to extract an adequate amount of toxins required for various studies.

10. Laboratory study on toxicity to fish

On the surface it appears that ciguatoxin has no effect on the well-being of fishes. Laboratory experiments will be conducted to determine the effects of ciguatoxin on the growth and physiology of fishes. Also, the rate of toxin uptake and retention will be investigated.

11. Extract pure toxins

Using methods developed at the University of Hawaii, extract and purify ciguatoxin, maitotoxin, and other toxins.

12. Determine the molecular structure of ciguatoxin and other toxins

The empirical formula for ciguatoxin is $(C_{35}H_{65}NO_8)_n$, and has been known for some time. Much is also known about the molecular structure of ciguatoxin. It is anticipated that the complete molecular structure of ciguatoxin will become known when an adequate supply of toxin is available. The molecular structure of other related toxins should be revealed when an adequate amount of toxins becomes available.

13. Synthesize ciguatoxin and other toxins

The determination of the molecular structure of ciguatoxin and related toxins will allow the synthesis of these toxins.

14. Select target tissues/organs/test animals

Determine appropriate and suitable tissues/organs/test animals for pharmacological studies.

15. Pharmacology

Determine the effects of ciguatoxin and other related toxins on selected target tissues/organs/test animals. Test off-the-shelf drugs to counteract the effect of ciguatoxin and other toxins.

16. Test treatment on animals for ciguatoxin and other toxins

Using the results obtained in subproject 15, conduct experiments with off-the-shelf drugs on test animals in test treatment to counter ciguatoxin and related toxins.

17. Develop treatment for human ciguatera intoxication

Conduct clinical trials and develop suitable treatment for human ciguatera intoxication using off-the-shelf drugs.

18. Develop usable enzyme-linked immunosorbent assay test for ciguatoxin

Studies are underway to develop an enzyme-linked immunosorbent assay (ELISA) to test for ciguatoxin. Work is continuing on this project and it is believed that a usable ELISA test will soon be available.

19. Conduct field trials

Conduct field trials of ELISA on marine organisms.

20. Develop "dipstick" test for ciguatoxin

Following the development of a usable ELISA test for ciguatoxin, experiments will be conducted to adapt ELISA for a "dipstick" test, which will be a simple test, applicable for field use by laymen.

21. Implement "dipstick" test and educate populace

Following perfection of the "dipstick" test for ciguatoxin, the test material will be made available for use by the general populace. An education program for the public will be carried out.

22. Undertake research on Hawaii and Federal rules and regulations

Hawaii and Federal rules and regulations concerning public agencies' responsibilities on testing wholesomeness of fish relative to ciguatoxin and other toxins will be examined.

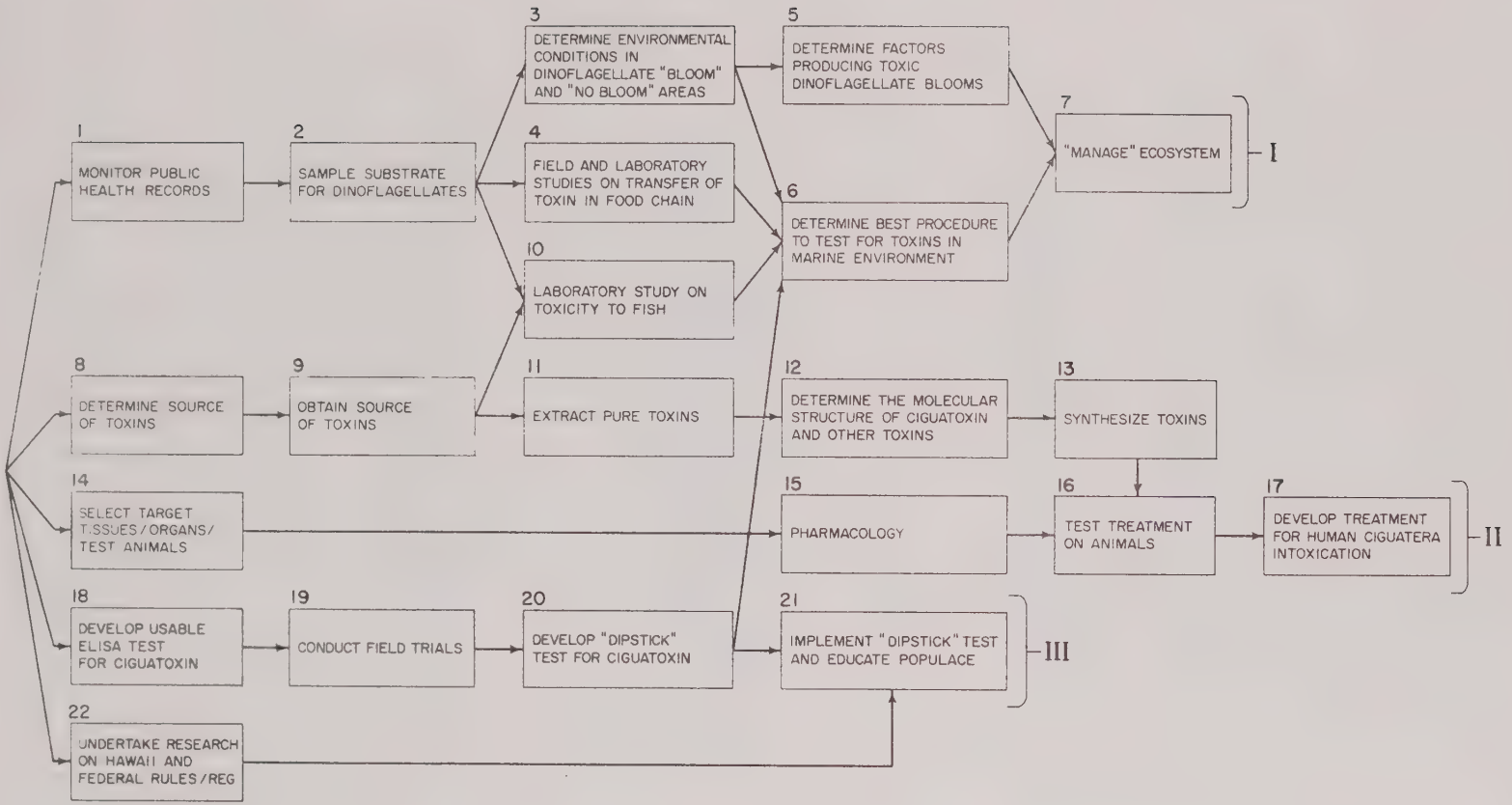

Figure 1.--Relationships of research activities/subprojects and objectives for ciguatera research in the Pacific.

APPENDIX A

SUMMARY REPORT OF THE PACIFIC CIGUATERA WORKSHOP HONOLULU, HAWAII, 18-20 MARCH 1981

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Cosponsored by the Honolulu Laboratory and the
University of Hawaii Sea Grant

May 1981

The Hawaii Ciguatera Workshop, cosponsored by the Honolulu Laboratory and the University of Hawaii Sea Grant (UHSG), was held at the Honolulu Laboratory, Southwest Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Honolulu, Hawaii from March 18 to 20, 1981. Mr. Richard S. Shomura, Honolulu Laboratory Director and Chairman of the workshop, opened the workshop by welcoming all the participants and observers and made a few introductory remarks including the rationale for holding the workshop. The objective of the workshop was to bring together some of the principal, active ciguatera researchers in the Pacific to help develop working hypotheses to guide future research on the ciguatera problem. It is recognized that the ultimate goal of ciguatera research is to fully understand the mechanism underlying the origin and transfer of the toxin(s) in the ecosystem and to develop corrective measures to provide nontoxic fish for human consumption.

The workshop agenda (Appendix 1) included the consideration of four broad areas or aspects of ciguatera research: toxins, the detection of toxins, the medical/pharmacological aspects of ciguatera, and the ecological aspects. Seven background papers were assembled for the workshop (Appendix 2) and nine working papers which described ongoing ciguatera research in the Pacific were presented (Appendix 3). In addition to the oral presentations on ciguatera research in the Pacific, presentations were made on the results of the recent World Health Organization meeting on ciguatera held in Noumea, New Caledonia, and on the status of ongoing ciguatera research in the southeastern United States. The workshop participants and observers are listed in Appendix 4.

TOXINS (WP/2, WP/6)

The discussion on toxins covered the topics of the chemical and molecular structure of ciguatoxin and other toxins and the origin of the toxins. The problem of solving the molecular structure of ciguatoxin has been hampered by the lack of an adequate supply of pure toxin for analysis. The toxin is diffusely distributed in minute amounts in the flesh and viscera of fishes so large amounts of toxic fish are needed to extract the toxin in a complex purification procedure. Dr. Paul Scheuer of the University of Hawaii (UH) now has 0.9 mg of ciguatoxin and Dr. Takeshi Yasumoto of Tohoku University, Sendai, Japan, has 0.4 mg. Although the analytic methods used to determine the molecular structure of the toxin is basically non-destructive, minute amounts of the toxin are lost in the analyses. Dr. Scheuer's 0.9 mg of ciguatoxin is presently at the California Institute of Technology for analysis. The basic, empirical formula of ciguatoxin, $(C_{35}\ H_{65}\ NO_8)_n$, has been known for some time. Although the molecular structure of ciguatoxin is not completely known, it is believed that the problem will be solved when more pure toxin becomes available. In this regard, it was announced that the UH will soon be acquiring a 300 MHz Nuclear Magnetic Resonance Spectrometer for the analysis of the molecular structure of complex compounds. This will greatly increase the instrument time available for the analysis of the molecular structure of ciguatoxin.

A breakthrough in ciguatera research occurred within the past 5 years when the source of ciguatoxin in the coral reef ecosystem was determined to be a benthic dinoflagellate, Gambierdiscus toxicus, a microscopic unicellular alga that grows primarily as an epiphyte on certain seaweeds on reef flats. This same species has been found near the Hawaii Institute of Marine Biology (HIMB)

in Kaneohe Bay and at other scattered locations around the island of Oahu. The results of experiments conducted at HIMB to determine the factors controlling toxin production, growth rate, and yields of laboratory cultures of the HIMB strain of G. toxicus were discussed. A problem in the research on culturing G. toxicus is the tremendous variability in the levels and kinds of toxins present in the cultures.

Elsewhere in the Pacific, the possible sources of secondary toxins have also been investigated. In addition to maitotoxin, the presence of secondary toxins have often been detected in the viscera of herbivorous fishes and it can be hypothesized that these secondary toxins, like ciguatoxin, originate from other benthic dinoflagellates. It was found that several species of dinoflagellates found growing with G. toxicus also produced toxins that were lethal to mice. Of interest are two fat soluble toxins of Prorocentrum lima, PL toxins I and II, which are practically indistinguishable in chromatographic properties from scaritoxin and ciguatoxin, respectively. A chemical and spectral analysis of PL toxin II showed that it is identical with okadaic acid, the cytotoxic component of a sponge.

DETECTION (WP/4, BP/2, BP/3, BP/6)

The early tests for ciguatoxin have been bioassays in animals such as mouse, cat, and mongoose. Among the shortcomings of these bioassays are that they are subjective and, in the case of the mongoose, the test animals are obtained from the wild and, therefore, are not homogeneous. A breakthrough in testing for ciguatoxin occurred with the development of a radioimmunoassay (RIA) for the direct examination of fish tissues for toxin. The advantages of the RIA are that it is simple and practical, relatively specific, and sensitive. One of the objectives of current research is to evaluate the RIA procedure for ciguatoxin based on two approaches: 1) identifying the reactive factor in the sheep anti-ciguatoxin serum used in the RIA, and 2) assessing the RIA procedure on fishes from clinically defined and documented cases of ciguatera intoxication and comparing results with those from nontoxic fish of the same species. The RIA results are also being evaluated by supportive bioassays, the mouse bioassay, and the guinea pig atrium assay.

There was much discussion on the technical aspects of the immunological reactions of the RIA procedure including questions on dose responses, extracts, and homogenates versus solids. It was pointed out that the whole basis of the RIA procedure is the assumption that ciguatoxin, being a lipid, is bound on the membrane surface or cells so that it can be detected by an antibody. Some of the difficulties associated with the RIA procedure is 1) sampling, i.e., there is uncertainty in the distribution of ciguatoxin in the fish flesh, 2) the possibility of false positives occurring in the RIA test and, 3) reproducibility owing to the fact that tissues are used and even within close proximity "hot spots" of ciguatoxin may vary.

Beginning in April 1979, at the request of the Hawaiian fishing industry and in cooperation with the Honolulu Laboratory, the RIA test was used to screen commercially landed kahala, Seriola dumerili, for ciguatoxin. The testing program made possible the marketing of large numbers of kahala larger than 20 pounds which, before the testing started, were ordinarily not marketed in the belief that large fish were more likely to be toxic. The most

significant result of the testing program has been the absence of any reported ciguatera cases from marketed RIA-negative kahala.

Mouse bioassays and guinea pig atrium assays have been used to evaluate the RIA procedure. Although the number of test samples is small, the data suggest direct correlations among the three assays. It was noted that ciguatoxin causes an initial massive release of neuroepinephrine in guinea pig atrium. However, one of the clinical symptoms of ciguatera intoxication in humans is reduced cardiac activity. In light of the effect of ciguatoxin on guinea pig atria, the question was posed regarding the effect of ciguatoxin on humans in the early stage of ciguatera intoxication.

Research is also underway to develop an enzyme-linked immunosorbent assay (ELISA) for ciguatoxin. ELISA is simpler and more rapid and unlike the RIA procedure, is not dependent on the use of radioisotopes. Current research on ELISA includes the establishment of toxicity ranges based on absorbence values of samples from clinically documented tissues from ciguatera intoxications and nontoxic tissues. A comparison of RIA and ELISA tests on kahala indicated that ELISA gave a lower rejection rate, which may be more realistic in light of the incidence of reported ciguatera intoxications by kahala in the past.

MEDICAL/PHARMACOLOGY (WP/7, WP/8, WP/9)

This section of the workshop dealt primarily with the public health aspect of ciguatera intoxication. The results of a study to determine the effect of ciguatera on the overall health of Pacific islands populations and how it has affected the utilization of marine resources were discussed. The study was an extensive comparative investigation of the perceived distribution and occurrence of ciguatera in the late 1970s, folk beliefs as to the etiology of the disease, and other aspects of the health and resource problems stemming from ciguatera. Statistics on ciguatera morbidity rates from the South Pacific Commission Health and Epidemiological Information Service (SEPHIS) area were presented. In 1978 the mean reported ciguatera morbidity rate for the area (excluding Papua New Guinea) was 12.01/10,000. The actual morbidity rate is undoubtedly considerably higher.

A summary of ciguatera intoxication in Hawaii covering a period from 1900-80 was presented. It was noted that cases of ciguatera intoxication were higher in the spring and autumn and that more patients rather than physicians are apt to report ciguatera poisonings. It was further noted that a 25% reporting rate is considered good.

A detailed account of the fatality caused by Marquesan sardine, Sardinella marquesensis, on Kauai in 1978 was also presented. Clinical data from this case were remarkably similar to what would be expected from a severe form of ciguatera intoxication, and it was suggested that clupeoid poisoning should not be excluded from the concern of those doing research on ciguatera poisoning. However, other workshop participants noted that clupeoid poisoning may be more closely related to paralytic shellfish poisoning (PSP) in ecological terms.

ECOLOGY (WP/1, WP/3, WP/5, WP/6, BP/1, BP/4, BP/5, BP/7)

Based on the correlation of the population density of G. toxicus with epidemiological information, the endemicity of ciguatera in various locations

in the Pacific was discussed. The results of surveys showed that the density of the G. toxicus population was correlated with fish toxicity. These results suggest that toxicity in any area can be predicted by the density of G. toxicus. Another possibility of a monitoring system for ciguatera is the assessment of the toxicity of fish livers. It has been shown that fish livers show far less variability in toxicity than the flesh of fishes.

The results of a study on the distribution of G. toxicus in French Polynesia (Tahiti and Gambier Island), New Caledonia, Guam, and Okinawa were also presented, including the effect of certain environmental factors on the density of G. toxicus. Temperature is not an important factor in the density of G. toxicus. However, salinity and light intensity appear to be important. Iron was not important in the growth of G. toxicus but phosphates significantly increased the growth.

Development of the RIA procedure made possible large-scale testing of fishes for ciguatoxin. As part of the cooperative survey of the marine resources in the Northwestern Hawaiian Islands (NWHI), the Honolulu Laboratory and the Hawaii Division of Fish and Game (HDFG) have been sampling inshore and nearshore fishes to determine the distribution of ciguatoxic fishes.

The Honolulu Laboratory's results of tests for ciguatoxin on fish and shellfish collected in the NWHI, Midway Islands, American Samoa and Western Samoa, and Guam and the Northern Mariana Islands were presented. The overall rejection (positive and borderline toxicity levels) rate was 15% for NWHI, 39% for Midway, 19% for American Samoa and Western Samoa, and 4% for Guam and the Northern Mariana Islands.

Flesh samples from fishes are obtained from the dorsal anterior region (A), ventral abdominal region (B), and the anal region (E). It was pointed out that there was no clear trend as to where (sites A, B, or E) the toxin is concentrated in the fish. The results were not only variable among species, but also between sexes. The results to date showed also that toxicity was not related to size or sex.

The results obtained by the HDFG indicate that fishes in the NWHI were relatively more toxic (in terms of numbers rejected in the RIA test) in the summers of 1977 and 1978 than in 1979 and 1980. In 1980 the nearshore fishes were more toxic in the fall than in the summer. Based on these results, it was suggested that the occurrence of ciguatoxic fishes appear to be cyclical. The feeding habits, distribution, and abundance of the fishes sampled were also described.

Also, some anomalous results in the HDFG data and the Honolulu Laboratory data were evident. In sampling around Midway in 1980, the Honolulu Laboratory samples indicated an overall high rejection rate for fishes caught from September 30 to October 4, whereas the HDFG samples collected around the same period showed a relatively low rejection rate.

The results of an analysis of data from the kahala sampling program between April 1979 and December 1980 were also discussed. The mean quarterly RIA scores showed a general trend of a decline in RIA scores from the second quarter of 1979 to a low at the end of 1979/beginning of 1980 and a subsequent increase in RIA scores through 1980. The trend was consistent for sampling

sites A, B, and E, for geographical origin of the fish (NWHI, Oahu, Penguin Bank, and Hawaii), and for both sexes. The correlation of RIA between sampling sites was high: (AB) = 0.74, (AE) = 0.69, and (BE) = 0.70. Also, the variation in RIA scores from two replicates from each sampling site (A, B, and E) was no greater than the variation among sampling sites A, B, and E. Other results indicated that: there was no relationship between kahala weight and RIA scores, and that sampling site B or E would be the best single site to sample for maximum RIA values.

Color slides of the various fish species implicated in ciguatera intoxication were shown and the distribution, food habits, and habitat of these fishes were described. The species that have caused ciguatera are shore fishes associated with reefs, are bottom-dwelling, but they may also be semipelagic open-water forms that range into the reef habitat to feed. They may be carnivorous or they may be benthic algal or detrital feeders. The carnivores that prey heavily on reef fishes are the most prone to be toxic whereas those that feed primarily on benthic crustaceans tend to be least toxic. The moray eel, Lycodontis (= Gymnothorax) javanicus, is highly toxic.

Other ecological aspects of ciguatera were also discussed. Young and old Hawaiian monk seals, Monachus schauinslandi, in the NWHI suffered high mortality in 1978. It was speculated that ciguatera intoxication could have been the cause of the mortality. In connection with this, the results of experiments where elephant seals, Mirounga angustirostris, were fed moray eels caught in the NWHI were described. Elephant seals were found to be highly susceptible to ciguatera intoxication.

RECOMMENDATIONS

The workshop identified three general objectives or goals for future ciguatera research. The first goal is to obtain an understanding of the factors or mechanisms triggering the chain of events leading ultimately to potential outbreaks of ciguatera intoxication so that these events could be predicted. The second goal is to elucidate the pharmacological aspects of ciguatera and to develop a viable treatment for ciguatera intoxication. The third goal is to develop and disseminate a quick and reliable field test to screen marine organisms for ciguatoxin and related toxins.

Several general areas of research were recommended to achieve the first objective:

1. Determine baseline conditions in (a) areas with no previous history of ciguatera outbreaks and (b) areas that could potentially produce ciguatera outbreaks. Related to this is the determination and verification of factors causing blooms of Gambierdiscus toxicus and the comparison of environmental conditions in areas containing and devoid of dinoflagellate blooms.

2. Verify the source of ciguatoxin in the reef ecosystem; determine the rate of toxin production from culture experiments and determine factors that influence the growth of toxin-producing dinoflagellates. Determine the source (cysts?) of dinoflagellate blooms.

3. Conduct field and laboratory studies to determine the transfer and metabolism of ciguatoxin in the food chain.

4. Determine the effects of ciguatoxin on fish including its toxicity to fish and its influence on growth rates; conduct experiments to determine if ciguatoxin is accumulated in fish or excreted and whether it would be possible to predict time/area fish toxicity based on dates/areas of dinoflagellate blooms; determine why some species are more toxic than others including a quantitative analysis of toxicity levels by species, size, and area, and compare findings with the food chain understanding; and determine whether crustaceans and molluscs in areas of dinoflagellate blooms are toxic.

5. Evaluate the ELISA technique for field work.

Research activities recommended to achieve the second goal were:

1. Determine source of toxin by locating toxic areas, e.g., by public health follow-ups, search for alternate source of ciguatoxin by bio-testing for possible new sources. A related activity is to determine factors that make dinoflagellates toxic.

2. Collect toxic fishes including moray eels, RIA-rejected kahala, and other species and develop cultures of Gambierdiscus toxicus to extract the crude toxins.

3. Assemble hardware and manpower to extract and purify toxins for experiments to a) compare toxin from moray eel with toxins from other species, b) determine the molecular structure of ciguatoxin and other toxins, and c) determine the metabolic pathways and target tissues/organs in tests on mice and other animals and muscle tissues, c) investigate the pharmacology of ciguatoxin to determine metabolic pathways and target tissues/organs, in tests on mice and other animals, and d) determine the efficacy of off-the-shelf drugs for the treatment of ciguatera in test animals and in clinical trials.

Research activities recommended for the third goal were:

Develop usable ELISA test for ciguatoxin and 1) improve specificity of ELISA test to sort out other toxins (scaritoxin, maitotoxin, okadaic acid) and 2) adapt ELISA procedure for a "dip stick" test.

APPENDIX 1

AGENDA

1. Introduction (R. Shomura)

    1.1 Participants
    1.2 Objectives of workshop

2. Report of SPC ciguatera meeting (A. Banner)

3. Toxins

    3.1. Chemical composition (P. Scheuer)
    3.2. Dinoflagellates (T. Yasumoto, N. Withers)

4. Detection

    4.1. RIA (Y. Hokama, L. Kimura)
    4.2 ELISA (Y. Hokama, L. Kimura)
    4.3 Muscle tests (J. Miyahara)

5. Medical/Pharmacology

    5.1. Case histories--Hawaii (M. Sugi)
    5.2 Case histories--Other Pacific areas (N. Lewis)
    5.3 Pharmacological (J. Miyahara)

6. Ecology

    6.1. Elaborators (T. Yasumoto, N. Withers)
    6.2. Fishes

        6.2.1. NWHI fishes (Honolulu Laboratory, Hawaii Division of Fish and Game)
        6.2.2. Kahala (Honolulu Laboratory)
        6.2.3. Other areas--American Samoa, western Pacific (Honolulu Laboratory)

    6.3. Other animals

        6.3.1. Hawaiian monk seal (Honolulu Laboratory)
        6.3.2. Others--birds, turtles (open)

APPENDIX 2

LIST OF BACKGROUND PAPERS

BP/1 Adachi, Rokuro, and Yasuwo Fukuyo.
1979. The thecal structure of a marine toxic dinoflagellate, Gambierdiscus toxicus gen. et sp. nov. collected in a ciguatera-endemic area. Bull. Jpn. Soc. Sci. Fish. 45:67-71.

BP/2 Hokama, Y., A. H. Banner, and D. B. Boyland.
1977. A radioimmunoassay for the detection of ciguatoxin. Toxicon 15:317-325.

BP/3 Hokama, Y., L. H. Kimura, and J. T. Miyahara.
In press. Immunological approaches to understanding marine toxins. Proceedings of the Sixth Food and Drug Administration Science Symposium on "Aquaculture - Public Health, Regulatory and Management Aspects," February 12-14, 1980, New Orleans, Louisiana (Office of Health Affairs, FDA).

BP/4 Humphreys, Robert L., Jr.
1980. Feeding habits of the kahala, Seriola dumerili, in the Hawaiian Archipelago. In Richard W. Grigg and Rose T. Pfund (editors), Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, April 24-25, 1980, University of Hawaii, Honolulu, Hawaii. Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-80-04, p. 233-240.

BP/5 Ito, Bernard M., and Richard N. Uchida.
1980. Results of ciguatera analysis of fishes in the Northwestern Hawaiian Islands. In Richard W. Grigg and Rose T. Pfund (editors), Proceedings of the Symposium on Status of Resource Investigations in the Northwestern Hawaiian Islands, April 24-25, 1980, University of Hawaii, Honolulu, Hawaii. Sea Grant Misc. Rep. UNIHI-SEAGRANT-MR-80-04, p. 81-89.

BP/6 Miyahara, J. T., C. K. Akau, and T. Yasumoto.
1979. Effects of ciguatoxin and maitotoxin on the isolated guinea pig atria. Res. Commun. Chem. Pathol. Pharmacol. 25:177-180.

BP/7 Randall, John E.
1980. A survey of ciguatera at Enewetak and Bikini, Marshall Islands, with notes on the systematics and food habits of ciguatoxic fishes. Fish. Bull., U.S. 78:201-249

APPENDIX 3

LIST OF WORKING PAPERS

WP/1 Polovina, Jeffrey J., and Bernard M. Ito.
An analysis of data from the kahala ciguatera sampling program, April 1979-December 1980.

WP/2 Withers, Nancy.
Pacific ciguatera.

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APPENDIX 4

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